2007

Computer modeling of landslides generated by the 1906 San Francisco earthquake

Mark W. Swank
San Jose State University

COMPUTER MODELING OF LANDSLIDES GENERATED BY THE 1906 SAN FRANCISCO EARTHQUAKE

A Thesis

Presented to

The Faculty of the Department of Geology

San José State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Mark W. Swank

August 2007

APPROVED FOR THE DEPARTMENT OF GEOLOGY

Dr. John W. Williams

Dr. Donald Reed

Dr. David K. Keefer
United States Geological Survey

APPROVED FOR THE UNIVERSITY

ABSTRACT

COMPUTER MODELING OF LANDSLIDES GENERATED BY THE 1906 SAN FRANCISCO EARTHQUAKE

by Mark W. Swank

On April 18, 1906, an earthquake with an estimated moment magnitude (Mw) of 7.8 struck the San Francisco Bay Region. The earthquake generated thousands of landslides, resulting in 40 deaths and property damage correlating to billions of dollars today. The Comprehensive Areal Model for Earthquake-Induced Landslides (CAMEL) is a new model for predicting both potential landslide hazards and the type of landslide generated. The model incorporates variables empirically determined to be important for earthquake-induced landslide occurrence: slope angle, moisture, material strength, slope height, soil depth, shaking intensity, terrain roughness, artificial slope disturbance, and vegetation condition. The model is based on fuzzy set theory (also called "computing with words") dealing with inevitable uncertainties in the input data by providing ranges in output data. Using Geographic Information Systems (GIS) technology, the model was used to provide earthquake-induced landslide hazard assessments of the San Francisco Bay Area utilizing the 1906 shaking intensity map.

ACKNOWLEDGEMENTS

I would like to specially recognize my lovely wife Kim. She motivated and supported me regardless of the extensive time required to complete my graduate degree. She supported me both financially and emotionally and without her I never would have succeeded in completing one of my life goals.

I would also like to thank the generous people at the USGS, in particular Dr. David Keefer, Dr. Scott Miles, and Luke Blair. Dr. Miles is the developer of the model I had the opportunity to implement. He was kind enough to spend two weeks updating CAMEL to operate with ArcGIS 9 and training myself and Luke on the subtleties. Without Luke's assistance the CAMEL model would have been a great challenge. He was willing to stay late and after hours as need be to work through the kinks and to teach me how to process the data.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Page

FIGURES

Page

TABLES

PLATES

INTRODUCTION

This study presents the results of the Comprehensive Areal Model of Earthquake-Induced Landslides (CAMEL) as applied to the 1906 San Francisco Earthquake. This project is part of a collaborative effort with researcher Dr. David K. Keefer at the United States Geological Survey (USGS) to create seismically-induced landslide hazard maps for the 1906 earthquake centennial and to demonstrate the applicability of the CAMEL model as an alternative to currently used methods for landslide hazard assessments. Professor Scott Miles created the model as part of his doctoral dissertation, under the guidance of Dr. Keefer, at the University of Washington in 2004. This research contributes to their efforts by increasing the understanding of how geologic processes and properties affect seismically induced landslides and by generating data layers to be used in a Geographic Information System (GIS)-based model. The goal of this thesis is to create earthquake-induced landslide hazard maps for the San Francisco Bay Area utilizing the 1906 shake intensity map.

CAMEL is a dynamic model created as an alternative to the standard methods of determining slope stability during strong ground motion. Currently four models are recognized, with the Newmark/Cumulative displacement model being utilized by the State of California to aid in determining landslide movement during earthquakes. Each of the existing models utilizes a number of assumptions that may result in potentially erroneous results. These gaps in information can be narrowed using the fuzzy-logic system employed by CAMEL.

The April 18, 1906, earthquake located in the San Francisco Bay Area, with an estimated moment magnitude of 7.8, produced thousands of landslides (Keefer, 1984), resulting in a number of casualties and millions of dollars in property damage. The increase in population density since 1906, accompanied by construction on susceptible slopes, necessitates the advancement of more conclusive and detailed models. CAMEL employs a 2-module system with the ability to separate the probabilities and hazards associated with each type of earthquake-induced landslide. Using a GIS-based model allows input layers to be dynamic, adjusting to the variability seen in natural conditions.

GEOLOGY

Setting

The San Francisco Bay Area is in the California Coast Ranges geomorphic province, a series of discontinuous northwest trending mountain ranges, ridges, and intervening valleys characterized by complex folding and faulting. The general geologic framework of the San Francisco Bay Area is illustrated in studies by Schlocker (1971) and the California Geological Survey (2002), as well as in studies by Wagner et al. (1991), Chin et al. (1993), Ellen and Wentworth (1995), Graymer et al. (2000), and Graymer et al. (2006) (Fig. 1).

Geologic and geomorphic structures within the San Francisco Bay Area are dominated by the San Andreas Fault (SAF) system, a series of mostly right-lateral strike-slip faults that extends from the Gulf of California in Mexico, to Cape Mendocino on the coast of Humboldt County in northern California. To the west of the San Andreas Fault is the Pacific Plate, which moves northwards relative to the North American Plate, located east of the fault. In the San Francisco Bay Area, movement across this plate boundary is distributed across a number of other faults that include the Hayward, Calaveras, and Concord. Together, these faults are referred to as the San Andreas Fault system. Movement along the San Andreas Fault system has been ongoing for about 25 million years. The northwest trend of the faults within this fault system is largely responsible for the strong northwest structural orientation of geologic and geomorphic features in the San Francisco Bay Area. Currently, active compressional forces normal to the northwest structural trend of the Coast Range province are also partially responsible for the strong northwest structural trend and uplift of the mountains within the province. These compressional forces are responsible for the movements associated with the Great Valley Fault system, a series of blind thrust faults along the eastern margin of the Coast Range province, and the folding of the younger rocks within the region (Brown, 1990).

Basement rocks west of the San Andreas Fault include granitic bodies, while to the east, the basement rocks consist of a chaotic mixture of highly deformed marine sedimentary, submarine volcanic and metamorphic rocks of the Franciscan Complex. Both are typically Jurassic to Cretaceous in age (205-65 million years old). Overlying the basement rocks are Cretaceous (about 140 to 65 million years old) marine, as well as Tertiary (about 65 to 1.7 million years old) marine and non-marine sedimentary rocks with some continental volcanic rock. These Cretaceous and Tertiary rocks have typically been extensively folded and faulted as a result of Late Tertiary and Quaternary regional compressional forces. The inland valleys as well as the structural depression within which the San Francisco Bay are filled with unconsolidated to semi-consolidated deposits of Quaternary age Continental deposits (alluvium, colluvium, and landslide deposits) consist of unconsolidated to semi-consolidated sand, silt, clay, and gravel while the Bay deposits typically consist of organic-rich silt and clay (Bay mud) or sand.

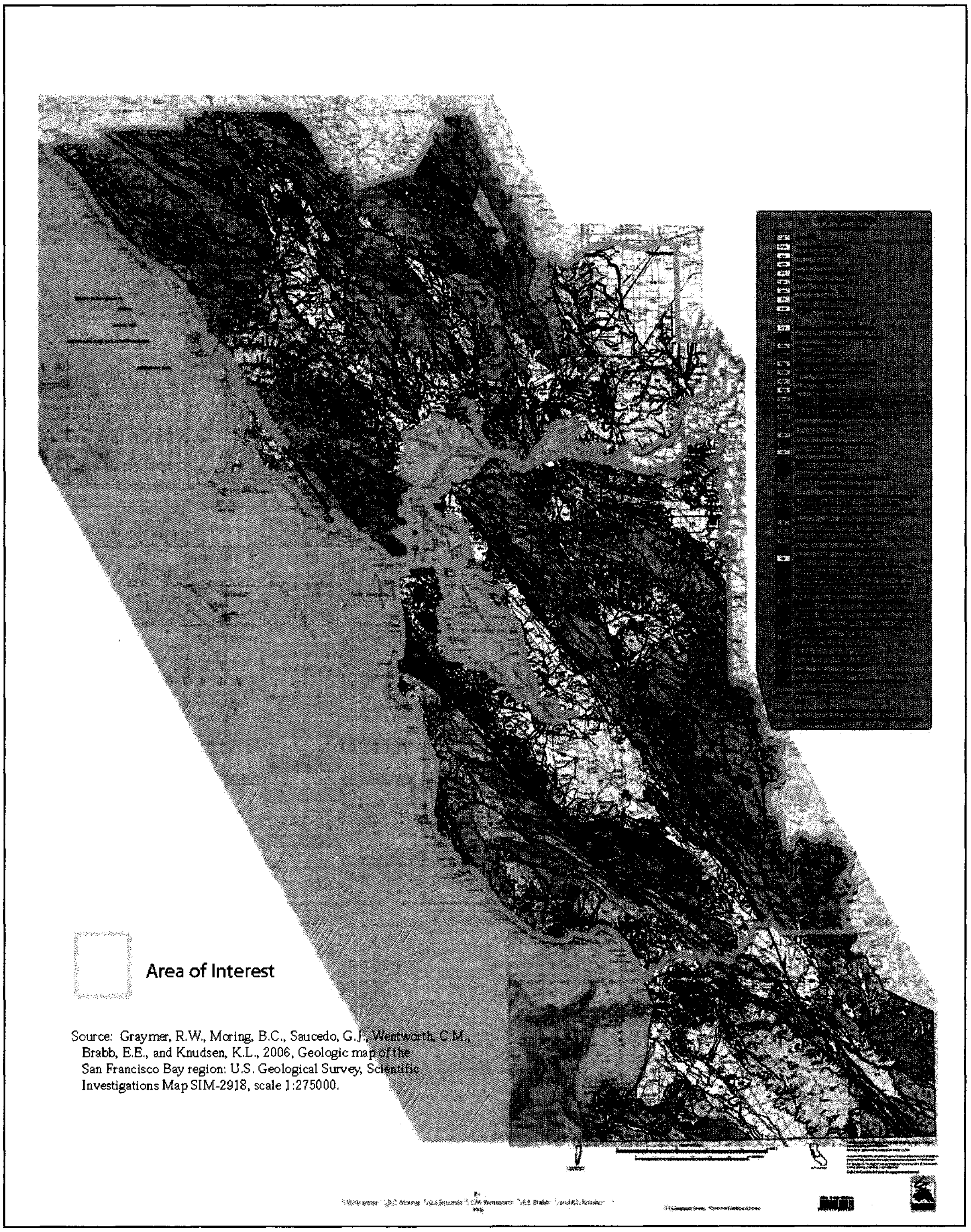
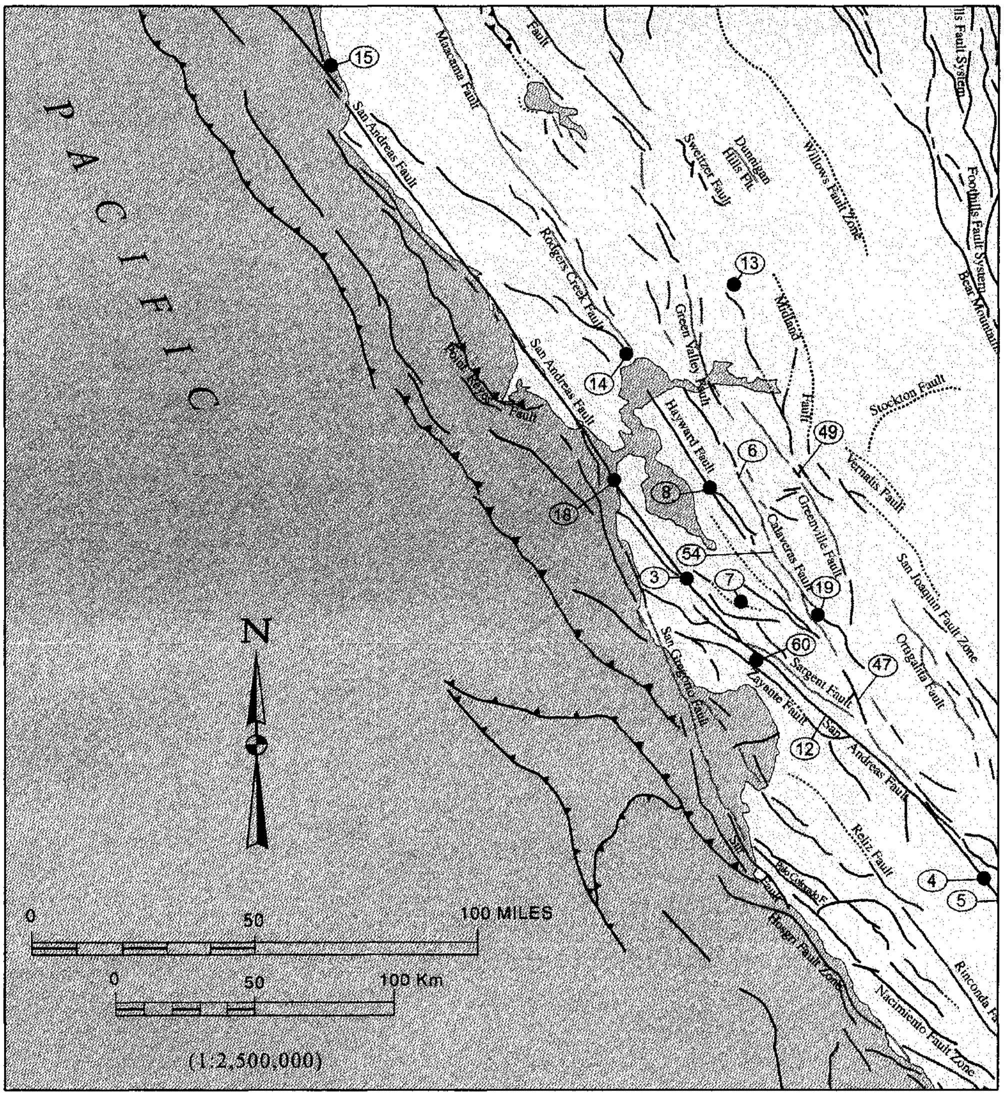


Figure 1. Geology of the San Francisco Bay Area with the Area of Interest (Graymer et al., 2006) (reprinted with permission from Graymer)

Faulting and Seismicity

The San Francisco Bay Area is a region characterized by numerous active faults and moderate to high seismic activity. Faults within the Greater Bay Area are shown on the Regional Fault Map (Fig. 2). Active faults are defined as experiencing seismic activity during historic time (since roughly 1800) or exhibit evidence of surface displacement during Holocene time (Hart and Bryant, 1997). Potentially active faults typically show evidence of displacement older than 11,000 years (Holocene age) and younger than 1.7 million years (Pleistocene age). Well-defined faults are recognizable by trained geologists by physical features at or just below the ground surface. The definition "inactive" generally implies faults that have not been active since the beginning of the Pleistocene Epoch (older than 1.7 million years old) (California Division of Mines and Geology, 1986).



EXPLANATION

- Fault with historic movement
- Fault with movement within the last 10,000 years
- Faults with movement older than 10,000 years or undifferentiated

Reference:
Jennings, C.W., 1994, Fault activity map of California and adjacent area, with locations and ages or Recent volcanic eruptions; California geologic data map series, map no. 6, Department of Conservation, Division of Mines and Geology

*Colors:
Purple = Pleistocene fault movement
Black = Pre-Quaternary fault movement

**Numbers in circles refer to significant earthquakes and fault ruptures

Figure 2. Faults in the San Francisco Bay Area (modified from Jennings, 1994) (reprinted with permission from California Geological Survey)

Table 1 below lists the faults and some of their seismic parameters within the San Francisco Bay Area. The locations of the faults and associated parameters in Table 1 are based on data presented by Jennings (1994), Wakabayashi and Smith (1994), Frankel et al. (1996, 2002), Petersen et al. (1996), ICBO (1998), Cao et al. (2003), and the Working Group on California Earthquake Probabilities (2003). The maximum earthquake magnitudes presented in this table are based on the moment magnitude scale developed by Kanamori (1977). The recurrence intervals of major earthquakes on these faults are also listed in Table 1.

Table 1. Faults within the San Francisco Bay Area (modified from Cao et al., 2003)

Fault Name	Fault Length (km)	Magnitude of Maximum Earthquake*	Slip Rate (mm/yr)	Recurrence Interval (yr)
San Andreas (SAS + SAP + SAN + SAO)	473	7.9	17 – 24	378
San Gregorio (SGS + SGN)	176	7.4	3 – 7	1202
Hayward – Rodgers Creek (HS + HN + RC)	150	7.3	9	3524
Calaveras (CS + CC +CN)	123	6.9	6 – 15	1555
Ortigalita	70	7.1	1	1153
Hunting Creek – Berryessa	60	7.1	6	194
Zayante-Vergeles	58	7	0.1	8821
Concord – Green Valley (CON + GVS + GVN)	56	6.7	4 – 5	580
Greenville (GS + GN)	51	6.9	2	1994
Point Reyes	47	7	0.3	3503

(Table 1 continued)

Great Valley (segment 7)	45	6.7	1.5	622
Monte Vista–Shannon	45	6.7	0.4	2410
Great Valley (segment 4)	42	6.6	1.5	472
Great Valley (segment 8)	41	6.6	1.5	483
West Napa	30	6.5	1	701
Great Valley (segment 5)	28	6.5	1.5	501
Mount Diablo Trust	25	6.6	2	389

**Moment magnitude*: An estimate of an earthquake's magnitude based on the seismic moment (measure of an earthquake's size utilizing rock rigidity, amount of slip, and area of rupture).

According to the 2001 California Building Code (CBC) Figure 16A-2 and Section 1629A.4.1, the San Francisco Bay Area lays primarily within Seismic Zone 4. The historically significant regional earthquake events include:

- 1838 (M7.0) San Francisco Peninsula earthquake,
- 1861 (M5.8) San Ramon Valley earthquake,
- 1868 (M7.0) Hayward earthquake,
- 1889 (M6.3) Antioch earthquake,
- 1980 (M5.8) Livermore earthquake,
- 1898 (M6.5) Mare Island earthquake,
- 1906 (M7.8) San Francisco earthquake,
- 1911 (M6.5) Calaveras fault earthquake, and
- 1989 (M6.9) Loma Prieta earthquake.

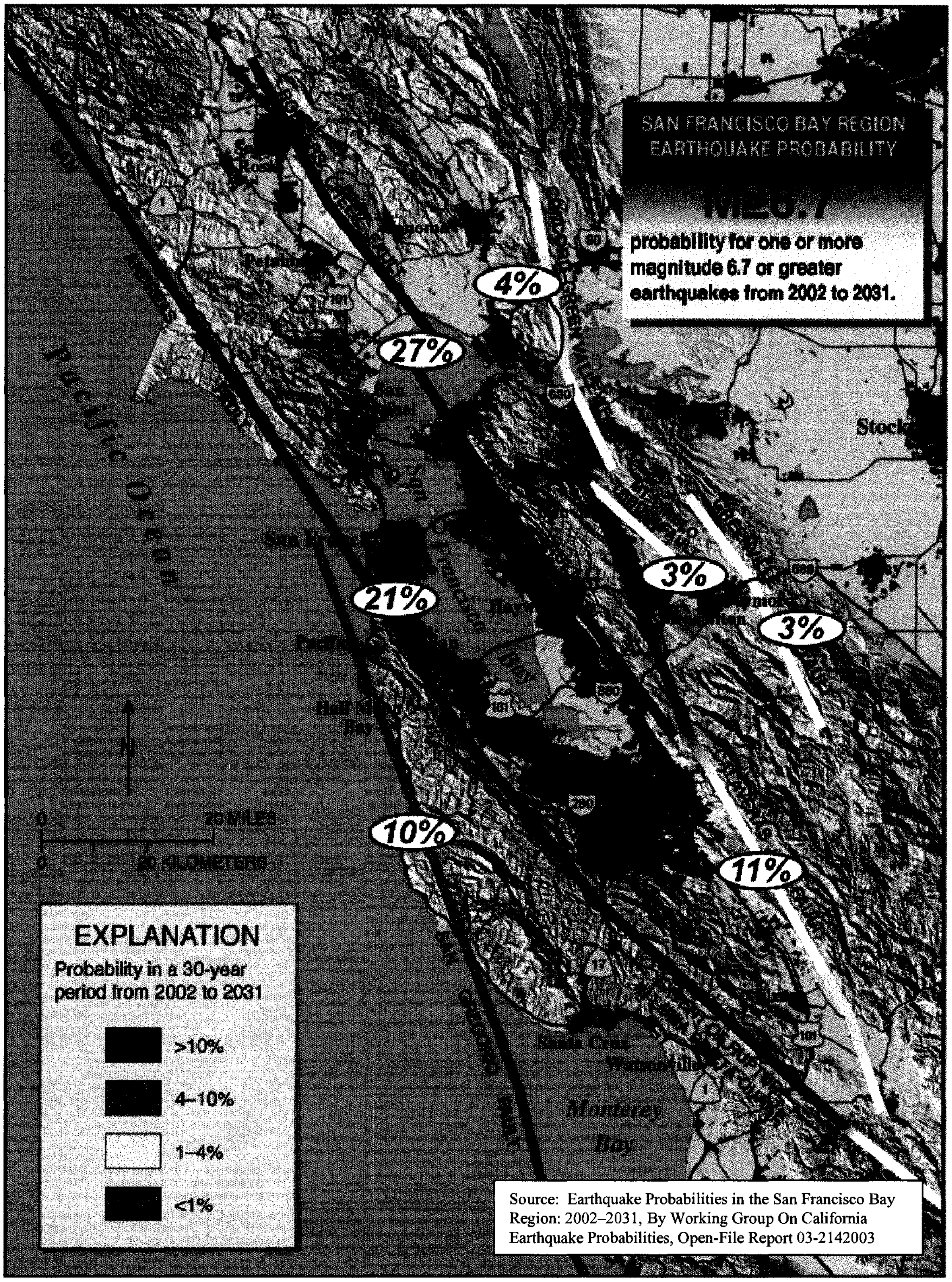


Figure 3. Seismic probabilities of faults in the San Francisco Bay Area (Working Group on California Earthquake Probabilities, 2003)

The Working Group on California Earthquake Probabilities (2003) has estimated a 79 percent chance that one of the major faults within the Bay Area will experience a major (M6.7+) earthquake during the period of 2003-2032 (Fig. 3). As has been demonstrated recently by the 1989 M6.9 Loma Prieta earthquake, the 1994 M6.7 Northridge earthquake, and the 1995 M6.9 Kobe earthquake, earthquakes of this magnitude range can cause severe ground shaking and significant damage to modern urban infrastructure.

1906 San Francisco Earthquake

The 1906 San Francisco Earthquake shake intensity map was used to create the landslide hazard maps for this study. on April 18, 1906 the San Andreas Fault ruptured with an epicenter offshore of San Francisco. The ground shaking lasted nearly 60 seconds, with the earthquake being felt from Oregon, to Los Angeles, to central Nevada. The earthquake ruptured the northernmost 296 miles of the San Andreas Fault from northwest of San Juan Bautista to the Cape Mendocino triple junction (Ellsworth, 1990).

Lawson's (1908) report noted a strong correlation between the shaking intensity and the underlying geologic conditions. The strongest shaking occurred in areas of fill along the edges of the San Francisco Bay and sediment-filled valleys. Although this earthquake is perhaps remembered most for the fire in San Francisco, giving it the somewhat misleading appellation of the "San Francisco Earthquake," shaking damage was equally severe in many other places along the fault rupture (Ellsworth, 1990).

EARTHQUAKE-INDUCED LANDSLIDES

Landslide investigations are an integral part of any post-earthquake analysis. Researchers have gained a better understanding of hazards associated with earthquakes with each concurrent event. Keefer (2002) chronicled the history of earthquake-induced landslides in, *Investigating Landslides Caused by Earthquakes – A Historical Review.* From this pool of information, and other studies by Keefer (1984; 1993; 1999; and 2000), a correlation between the abundance of earthquake-induced lanslides and several important factors was determined. The earthquake magnitude, slope, geologic material, and distance from the source determine, in large part, the types and number of landslides. Table 2 below shows the relative abundance of earthquake-induced landslides from a database of 40 earthquakes that occurred around the world. The abundance of the types of slides occurring during earthquakes played an important role in the development of CAMEL as a means of predicting areas of slope stability. In Table 2 below, the term "soil" is equivalent to the phrase "earth and debris".

Table 2. Relative abundance of landslides for 40-earthquakes occurring worldwide (Keefer, 1984) (reprinted with permission from Keefer)

Landslide Type, Listed in Order of Decreasing Total Numbers
Very Abundant: > 100,000 Landslides
Rock Falls
Disrupted Rock Slides
Disrupted slides in earth and debris
Abundant: 10,000 to 100,000 Landslides
Lateral spreads in earth and debris
Slumps in earth and debris
Block slides in earth and debris
Avalanches in earth and debris
Moderately Common: 1,000 to 10,000 Landslides
Falls in earth and debris
Rapid soil flows in earth and debris
Rock slumps
Uncommon: <1,000 Landslides
Subaqueous landslides
Slow earth slides
Rock block slides
Rock avalanches

The different types of landslides listed above in Table 2 require a minimum magnitude earthquake in order to occur. The approximate magnitude of the smallest earthquake causing landslides of various types was measured by Keefer (1984) to be ~4.0 for rock falls, rock slides, soil falls, and disrupted soil slides; ~4.5 for soil slumps and soil block slides; ~5.0 for soil lateral spreads, rapid soil flows, subaqueous landslides, rock slumps, rock block slides, and slow earth flows; ~6.0 for rock avalanches; and ~6.5 soil avalanches. In addition, a positive correlation between the earthquake magnitude and the size of the affected area was identified (Fig. 4).

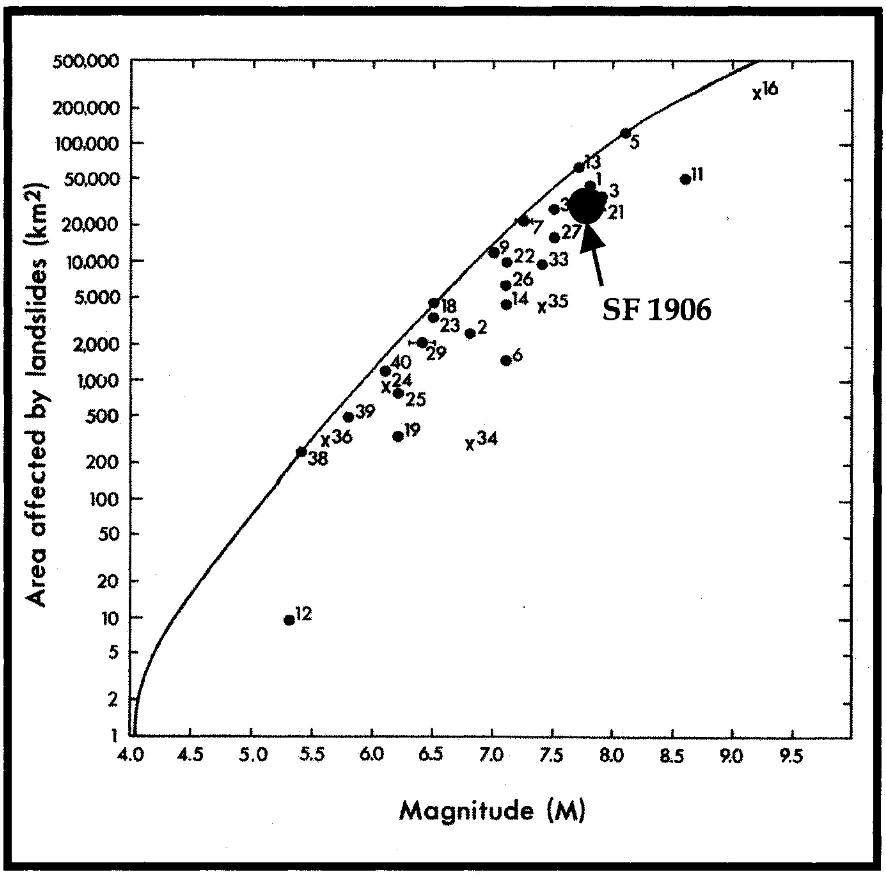


Figure 4. The magnitude of an earthquake impacts the total area affected (Keefer, 2006) (reprinted with permission from Keefer)

The slopes on which landslides occur can range from overhanging cliffs in well-indurated bedrock to unconsolidated sediments with nearly flat surfaces. Minimum slopes for various types of landslides range from less than 1° to 40° (Keefer, 1984, Rodríguez et al., 1999, and Hancox, 2002). Although certain landslide types can initiate on slopes as low as a few degrees, the most frequently occurring landslides occur at greater slope angles (Fig. 5). The most abundant landslides (rock falls, disrupted rock slides, disrupted slides in earth and debris)(Table 2) initiate on slope angles greater than 15°.

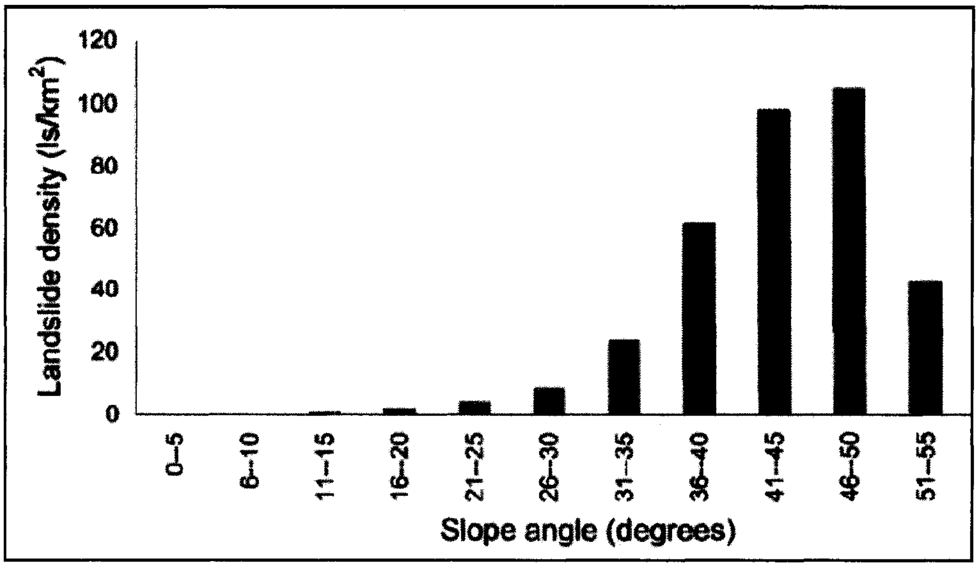


Figure 5. Relationship between landslide concentrations with increasing slope angle from a study of landslides caused by the 1994 Northridge earthquake (Parise and Jibson, 2000) (reprinted with permission from Jibson)

Keefer (2000) examined variations in landslide concentration and geologic units in areas shaken by the 1989 Loma Prieta, California earthquake by grouping the units based on descriptions of the lithology and associated shear strengths. Interestingly, though other studies, including the Newmark method, utilize shear strength values, no statistical correlation could be found between landslide concentration and these values. The description of the lithology (e.g. "unconsolidated and semi-consolidated sediments"; "weakly cemented sandstones and siltstones"; "moderately cemented mudstones, siltstones, and shales"; "moderately cemented sandstones"; and, "well-indurated igneous and metamorphic rocks") showed a significant statistical relation to landslide concentration. Keefer's (2000) findings show, lithologies such as igneous, metamorphic, and the Franciscan Complex rocks (typically the best-indurated materials), had lower average landslide concentrations than moderately and weakly indurated rocks; moderately indurated sedimentary rocks had intermediate landslide concentration values, with sandstone averages being lower than finer-grained rocks. Unconsolidated and semi-consolidated units had anomalously low landslide concentrations, a probable result of gentle slopes.

According to Keefer (1984), the materials most susceptible to landslide generation are:

1. Weakly cemented, weathered, sheared, intensely fractured, or closely jointed rocks;
2. Better-indurated rocks having prominent discontinuities;
3. Sandy residual or colluvial soils;
4. Saturated volcanic soils containing sensitive (a.k.a. quick) clays;
5. Loess;
6. Cemented soils;
7. Granular deltaic sediments;
8. Granular flood-plain alluvium; and,
9. Uncompacted or poorly compacted, granular artificial fill.

The landslide concentration is also a function of proximity to the earthquake epicenter and fault rupture. Keefer (200) found a correlation between the landslide concentration and the distance to the epicenter, with a significant decrease in the number of landslide per square kilometer with increasing distance. If a susceptible area is located within 10 kilometers of the epicenter, a marked increase in concentration is seen. At greater distances, the landslide concentration becomes more of a factor of other properties impacting earthquake-induced landslide.

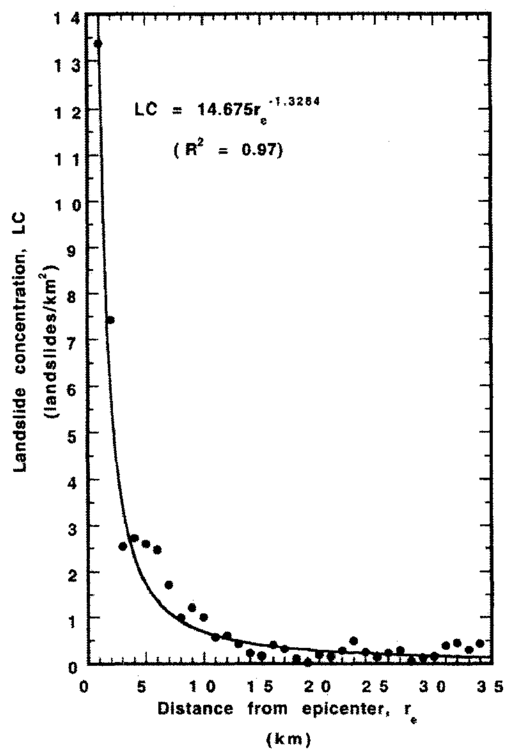


Figure 6. Concentration of landslides with distance from the earthquake (Keefer, 2000) (reprinted with permission from Keefer)

Landslide Nomenclature

A few taxonomies of landslide types exist in the literature; most useful for analyzing earthquake-induced landslides is that of Keefer (1984), which categorizes landslides by: material (rock or soil), type of movement, internal disruption, water content, velocity, and depth. According to these characteristics, landslides are grouped into three categories: (I) disrupted slides and falls, (II) coherent landslides, and (III) lateral spreads and flows. Categories I and II landslides occur in both rock and soil, while Category III landslides occur only in soil. The categories and individual landslide types of Keefer (1984) are illustrated in Figure 7. Whether the material is defined as rock or soil is based on the condition of the material prior to landslide movement. Keefer (1984) defined rock as "firm, intact bedrock," and soil as "a loose, unconsolidated, or poorly cemented aggregate of particles, which may or may not contain organic material." Typically the differentiation between rock and soil is gradational, dependent on the degree of physical or chemical weathering the material has experienced. The landslides are grouped as they appear on the hazard maps created for this thesis and only those landslides modeled by CAMEL are discussed.

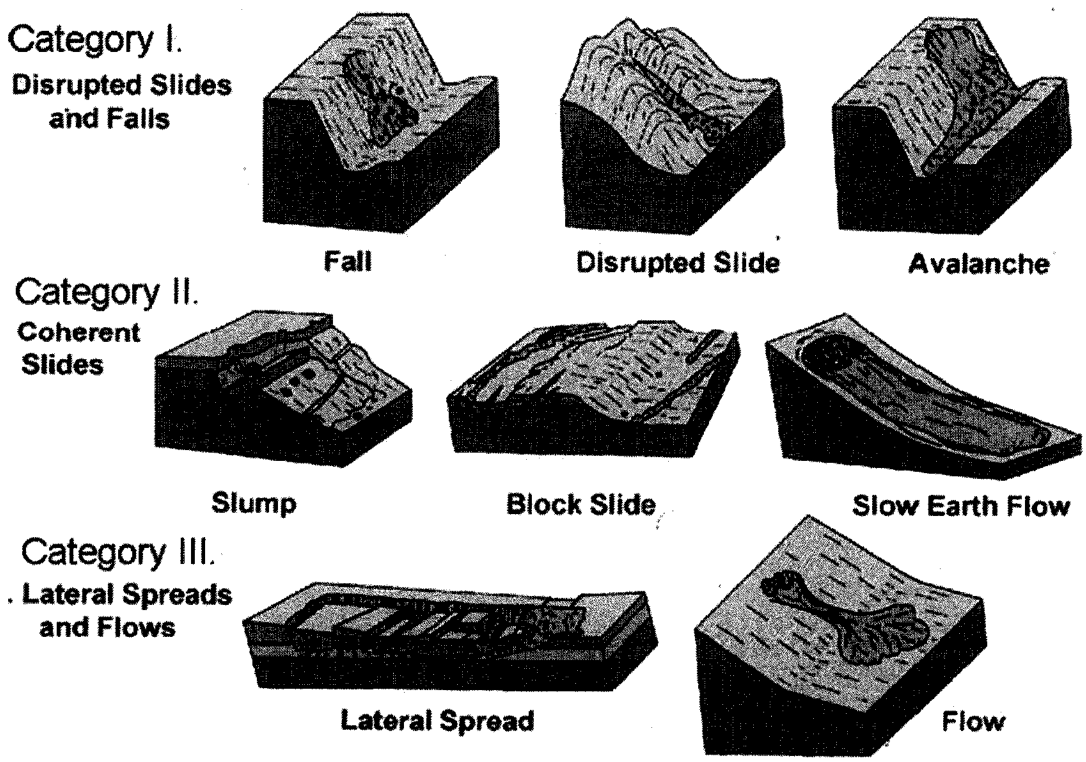


Figure 7. Categories of landslides (Keefer, 1984) (reprinted with permission from Keefer)

Category I

Category I landslides include disrupted slides, falls, and avalanches of both soil and rock because these landslides typically disaggregate to a large degree during initiation or movement. Landslides in this category originate on steep slopes, move at high velocities, and may transport material relatively long distances. Free fall may occur if the slope is in excess of 76 degrees with the falling mass striking a slope with less inclination — possibly bouncing upon impact depending on the type of material in motion (Ritchie, 1963). On longer slopes with angles at or below 45 degrees, the material movement is characterized by rolling rather than bouncing or free falling. However, changes in slope angles in the path of the landslide could restart the sequence of falling-bouncing-rolling. In CAMEL these are the soil and rock falls, disrupted soil and rock slides, and rock avalanches.

Rock Falls and Disrupted Rock Slides Rock falls are the most abundant of the earthquake-induced landslides. Falls start with the extrication of soil and/or rock from a steep slope, along which little or no shear displacement occurs. Rock falls are individual boulders or disrupted masses of rock that move very rapidly, typically through the air by falling, bouncing, or rolling. Earthquake-induced rock falls typically occur in closely jointed or weakly cemented materials including pumice, tuff, shale, siltstone, sandstone, and conglomerate (Keefer, 1984). Rock falls originate only on slopes steeper than 40^{o}, typically on narrow spurs, ledges, ridge crest, and man-made cuts.

Disrupted rock slides move by translational sliding, disrupted during movement into masses of rock fragments and blocks that slide on planar or gently curved surfaces where joints, bedding planes, or other surfaces of discontinuity down-dip out of the slope. Rock slides involve similar materials as rock falls but occur in hillside channels with slopes of 35^{o} or more. Disrupted slides will activate under any moisture conditions, from dry to completely saturated.

<u>Soil Falls, Disrupted Soil Slides, and Soil Avalanches</u> Soil falls are very similar to rock falls in most respects. Soil falls are blocks or disrupted masses of soil that bound, roll, and/or free-fall down slopes. Most soil blocks break apart during movement and upon impact. Typically, soil falls materialize along coastal bluffs, canyon walls, stream banks, terrace faces, and cut slopes. Most soil falls involve weakly cemented gravel and sand but a few may occur in unconsolidated or weakly cemented clay (Keefer, 1984). Because of the lower number of slopes meeting the requirements for soil falls, their occurrence is much less abundant than rock falls.

Disrupted soil slides consist of sheets of soil up to a few meters thick that disaggregate during movement into an assortment of small blocks and individual grains. Typically soil slides move along a basal shear surface formed at the soil-bedrock interface or at boundaries between different soil layers though some move on basal zones of weakened sensitive clays. Sensitive (or quick) clays become cohesionless, and behave similar to a fluid, when the bonds between clay particles and adsorbed films of water are broken during vibration (Easterbrook, 1999). The materials most commonly involved in disrupted soil slides are loose, unsaturated, residual or colluvial sand with little or no clay fraction (Keefer, 1984). The minimum slope inclination for disrupted soil slides is 15°.

Rock Avalanches Rock avalanches are landslides that disintegrate into streams of rock fragments. They are extremely fast moving flows of normally dry debris created by large falls and slides with velocities that may exceed 50 m/sec (Hsu, 1975). The motion of rock avalanches may depend on turbulent grain flow with dispersive stresses arising from momentum transfer between colliding particles (Cruden and Varnes, 1996). Source-slope inclination and height, based on 50 observed rock avalanches, show that the minimum inclination and height are, 25 ° and 150 m, respectively (Keefer, 1984). Table 3 below summarizes disrupted slides and falls of Category I.

Table 3. Category I Landslide types (modified from Keefer, 1984) (reprinted with permission from Keefer)

Name	Type of Movement	Internal Disruption[a]	Water Content[b] D	U	PS	S	Speed[c]	Depth[d]	Abundance in Earthquakes
Disrupted Slides and Falls									
Rock Falls	Bounding, rolling, free fall	High or very high	x	x	x	x	Extremely rapid	Shallow	Very abundant
Rock Slides	Translational sliding	High	x	x	x	x	Rapid to extremely rapid	Shallow	Very abundant
Rock Avalanches	Complex, involving fall, sliding, and (or) flow	Very High	x	x	x	x	Extremely rapid	Deep	Uncommon
Soil Falls	Bounding, rolling, free fall	High or very high	x	x	x	x	Extremely rapid	Shallow	Moderately Common
Disrupted Soil Slides	Translational sliding	High	x	x	x	x	Moderate to rapid	Shallow	Very abundant
Soil Avalanches	Translational sliding with subsidiary flow	Very High	x	x	x	x	Very rapid to extremely rapid	Shallow	Abundant

[a]Internal disruption "slight" signifies landslide consists of one or a few coherent blocks; "moderate" signifies several coherent blocks; "high" signifies numerous small blocks and individual soil grains and rock fragments; "very high" signifies nearly complete disaggregation into individual grains or small rock fragment

[b]Water Content: D=dry, U=Moist but unsaturated, PS=Partially saturated, S=Saturated

[c]Speed: very slow=0.6 - 1.5 m/yr.; slow=1.5 m/yr. - 1.5 m/mo; moderate=1.5 m/mo. - 1.5 m/day; rapid=1.5 m/day - 0.3 m/min; very rapid=0.3 m/min - 3 m/sec.; extremely rapid=>3 m/sec.. (Terminology from Varnes, 1978)

[d]Depth "shallow" signifies thickness generally <3 m, "deep" signifies depth generally >3 m

Category II

Keefer (1999) defines coherent landslides as block slides, slumps, and slow earth slides because they remain relatively intact during movement, generally consisting of one to several large blocks separated by fissures and grabens. Category II landslides move by three different mechanisms: block slides by translational sliding on relatively planar basal shear surfaces; slumps along basal shear surfaces curving concave upward so a headward rotation of the landslide occurs; and, slow earth slides by a combination of translational sliding and internal flow, with sliding predominating. Typical velocities of Category II landslides are low (<0.005 m/s) with relatively low displacements (<100 m). Rock/soil block slides and rock/soil slumps are generally deep-seated landslides. CAMEL cannot currently model slow earth slides.

Rock Block Slides and Rock Slumps Rock block slides consist of one or a few blocks sliding on planar basal shear surfaces involving little or no rotation. The shear planes are along discontinuities or bedding planes dipping out of the slope; therefore, the blocks move relatively coherently. Rock block slides typically originate on slopes steeper than 15° in materials such as tuff, andesite, weakly cemented pumice, and weakly cemented or closely jointed shale, mudstone, siltstone, and sandstone.

Rock slumps consist of one or a few coherent blocks sliding on a basal shear surface curving upward causing a headward rotation. Generally, rock slumps develop on 15° slopes. Rock slumps have a tendency to form in basalt with interbedded ash and breccia, pumice, andesite, granite, greenstone, slate, schist, amphibolite, siltstone, shale, and sandstone typically due to weak cementation, close jointing, weathering, and/or shearing.

Soil Block Slides and Soil Slumps Like rock block slides, soil block slides move translationally on planar or gently curved shear surfaces. This movement creates grabens at the landslide head, with internal fissures and pressure ridges at the toe. Most soil block slides are produced by fill, alluvial materials, till, volcanic ash, colluvium, clayey playa sediment, sandy eolian sediment, sandy alluvial-fan sediment, and periglacial sediment (Keefer, 1984). Many soil block slides involve flat-topped slopes and near-horizontal basal shear surfaces on slope inclination as low as 5°.

Soil slumps are very similar to rock slumps in most respects. As with rock slumps, soil slumps slide with a similar mechanism of movement -- curved, basal shear surfaces with headward rotation of the slump. These landslides are characterized by crescent-shaped scarps, blocks with surfaces tilted back toward the crests of slopes, and bulging toes. Slumps occur in a wide variety of materials, and most commonly in uncompacted and poorly compacted fills (sands and silts) with a minimum inclination of 10°. The Table 4 below summarizes characteristics of coherent landslides of Category II.

Table 4. Category II Landslide types (modified from Keefer, 1984) (reprinted with permission from Keefer)

Name	Type of Movement	Internal Disruption[a]	Water Content[b]				Speed[c]	Depth[d]	Abundance in Earthquakes
			D	U	PS	S			
Coherent Slides									
Rock Slumps	Rotational sliding	Slight or moderate	?	x	x	x	Slow to rapid	Deep	Moderately Common
Rock Block Slides	Translational sliding	Slight or moderate	?	x	x	x	Slow to rapid	Deep	Uncommon
Soil Slumps	Rotational sliding	Slight or moderate	?	x	x	x	Slow to rapid	Deep	Abundant
Soil Block Slides	Translational sliding	Slight or moderate	?	?	x	x	Slow to very rapid	Deep	Abundant
Slow earth flows	Translational sliding with minor internal flow	Slight or moderate			x	x	Very slow to moderate with very rapid surges	Generally shallow, occasionally deep	Uncommon

[a]Internal disruption "slight" signifies landslide consists of one or a few coherent blocks; "moderate" signifies several coherent blocks; "high" signifies numerous small blocks and individual soil grains and rock fragments; "very high" signifies nearly compete disaggregation into individual grains or small rock fragment

[b]Water Content: D=dry, U=Moist but unsaturated; PS=Partially saturated; S=Saturated

[c]Speed: very slow=0.6 - 1.5 m/yr.; slow= 1.5 m/yr. - 1.5 m/mo; moderate= 1.5 m/mo. - 1.5 m/day, rapid= 1.5 m/day - 0.3 m/min; very rapid=0.3 m/min. - 3 m/sec.; extremely rapid= >3 m/sec.. (Terminology from Varnes, 1978)

[d]Depth: "shallow" signifies thickness generally <3 m, "deep" signifies depth generally >3 m

Category III

Category III landslides include rapid soil flows, soil lateral spreads, and subaqueous landslides. The mechanisms causing soil lateral spreads are significantly different than the other types of landslides; therefore, CAMEL was not designed to model them. Subaqueous landslides are also not modeled by CAMEL. Because CAMEL does not model the latter two landslides, neither will be discussed further.

<u>Rapid Soil Flows</u> Rapid soil flows move as a stream of soil grains that flow viscously at high velocities and are typically, but not necessarily, partially or completely saturated. Rapid soil flows can initiate on inclinations as low as a few degrees, traveling several kilometers and transporting large boulders (Keefer, 1984). Table 5 below summarizes characteristics of flows and spreads of Category III.

Table 5. Category III Landslides (modified from Keefer, 1984) (reprinted with permission from Keefer)

Name	Type of Movement	Internal Disruption[a]	Water Content[b] D	U	PS	S	Speed[c]	Depth[d]	Abundance in Earthquakes
Lateral Spreads and Flows									
Rapid soil flows	Flow	Very High	?	?	?	x	Generally rapid to extremely rapid	Shallow	Moderately common
Soil lateral spreads[e]	Translation on zone of liquefied or sensitive material	Generally moderate; occasionally slight or high			x	x	Very rapid	Variable	Abundant
Subaqueous landslides[e]	Complex, generally lateral spreading and (or) flow; occasionally sliding	Generally high or very high			x	x	Generally rapid to extremely rapid; occasionally slow to moderate	Variable	Uncommon

[a]Internal disruption "slight" signifies landslide consists of one or a few coherent blocks; "moderate" signifies several coherent blocks; "high" signifies numerous small blocks and individual soil grains and rock fragments; "very high" signifies nearly compete dissaggregation into individual grains or small rock fragment

[b]Water Content: D= dry; U= Moist but unsaturated; PS = Partially saturated; S= Saturated

[c]Speed: very slow =0.6 - 1.5 m/yr.; slow= 1.5 m/yr. - 1.5 m/mo.; moderate= 1.5 m/mo. - 1.5 m/day; rapid= 1.5 m/day- 0.3 m/min.; very rapid =0.3 m/min. - 3 m/sec.; extremely rapid =>3 m/sec.. (Terminology from Varnes, 1978)

[d]Depth: "shallow" signifies thickness generally <3 m; "deep" signifies depth generally >3 m

[e]Not included in determinations of total volume

EARTHQUAKE-INDUCED LANDSLIDE MODELING

Previous Work

There are four (pseudo-static, Newmark displacement, Makdisi-Seed, and dynamic stress/stress deformation) generally accepted methods of slope stability analysis for seismic loading conditions of which only two, the pseudo-static and Newmark analysis, have practical applications for most residential and commercial development projects (California Division of Mines and Geology, 1997).

Pseudo-Static

The pseudo-static analysis is the simplest approach to a dynamic slope stability study and is calculated by having the earthquake load simulated by equivalent static horizontal acceleration acting on the mass of the landslide in a limit-equilibrium analysis (Hunt, 1948; Janbu, 1973; Chowdbury, 1978; Morgenstern and Sangrey, 1978; Bromhead; 1986; Nash, 1987; Duncan, 1996). The pseudo-static method is inherently conservative because a constant force equal to the maximum transient force replaces the cyclic loading due to the earthquake. To account for this conservatism, the analysis is designed for a factor of safety that is lower for the pseudo-static analysis than for the static analysis (e.g. under equal conditions an acceptable static factor of safety for a rock slope may be 1.25 to 1.5, an acceptable factor of safety under pseudo-static conditions may be 1.0 to 1.1) (Norrish and Wyllie, 1996). Although the method has recognized limitations, it remains the most frequently utilized method of determining earthquake-induced landsliding (California Division of Mines and Geology, 1997).

Newmark Displacement

The second common procedure for determining slope stability during ground motion is known as the Newmark or cumulative displacement analysis (Newmark, 1965; Makdisi and Seed, 1978; Wilson and Keefer, 1983, Hynes and Franklin, 1984; Houston et al., 1987; Jibson, 1993). Newmark or cumulative displacement analysis is determined by calculating the yield acceleration, defined as the inertial force required to cause the static factor of safety to reach 1.0, from the traditional limit-equilibrium slope stability analysis.

The Newmark analysis models a highly idealized and simplistic failure mechanism; thus the calculated displacements should be considered order-of-magnitude estimates of actual field behavior. A large component of determining material strengths in this analysis is the use of shear strengths (McCrink, 2001) which were found by Keefer (2000) to have no correlation to landslide concentration values during the 1989 Loma Prieta Earthquake. Newmark displacement analyses provide an index of probable seismic slope performances, although considerable judgment is required in evaluating seismic stability in terms of Newmark displacements rather than being an accurate predictor of observable landslide displacement in the field (California Division of Mines and Geology, 1997). The Newmark displacement model is being used by the California

Geological Survey (CGS) to create the seismic hazard maps for earthquake-induced landslides and liquefaction in the state of California.

Makdisi-Seed

Using a modified Newmark analysis, the Makdisi-Seed method (Makdisi and Seed, 1978) determines seismic embankment stability in terms of acceptable deformations in lieu of conventional factors of safety. Their method presents a rational means to determine yield acceleration, or the average acceleration required to produce a factor of safety of unity. This value, in turn is affected by the cyclic yield strengths of embankment materials, which turned out to be about 80 percent of static strength. Design curves were developed to estimate the permanent earthquake-induced deformations of embankments 10 to 200 feet high using finite element analysis. This method is currently used primarily for stability studies of landfills and highway embankments (California Division of Mines and Geology, 1997).

Dynamic Analysis/Stress-Deformation Analysis

The dynamic analysis (Cotecchia, 1987) or stress-deformation analysis (Kramer, 1996) is the most sophisticated of the four methods for determining seismic slope stability. The method typically utilizes a finite-element/finite-difference mathematical model. Ground motion analysis is incorporated in the form of an acceleration time history. The permanent strains resulting from an earthquake in each block of the finite element mesh are integrated to obtain the permanent deformation of the slope. The results of the analysis include a time history of the compressive and tensile stresses, natural frequencies, effects of damping, and resulting slope displacements (California Division of Mines and Geology, 1997).

CAMEL

The Comprehensive Areal Model of Earthquake-Induced Landslides (CAMEL) is a new, regional-scale computer model for earthquake-induced landslide hazards, developed by Scott Miles (2004) using fuzzy logic systems, a component of the computing with words (CW) methodology. The objective of CAMEL is to resolve some of the current limitations in other earthquake-induced landslide hazard models and to create hazard maps that are more detailed and useful for regulatory decision-making.

CAMEL by implements a decision support analyses structure developed by Wu et al. (1996) for landslide models which:

1. Provides information regarding the spatial and temporal likelihood of occurrence
2. Evaluates hazards of specific landslide types
3. Provides information about landslide sizes and velocities
4. Characterizes, propagates, and conveys uncertainty
5. Examines possible consequences for specific landslide types

Of the five requirements, three (numbers 1, 2, and 4) were utilized in the development of CAMEL. The prediction of spatial probability, as opposed to an aspatial index of performance such as Newmark displacement, is expressed as areal landslide concentration (number of landslides per square kilometer). This is based on studies by Liao et al. (2002), Keefer (1993, 2000), and Parise and Jibson (2000). Secondly, CAMEL produces six maps modeling distinct earthquake-induced landslide types – three for rock material and three for soil material. CAMEL does not currently model soil lateral spreads, a common type of earthquake-induced landslide. CAMEL deals with uncertainty through a fuzzy logic system. Currently, CAMEL cannot determine landslide size and velocity nor has the ability to evaluate the consequences of each type of landslide. Although CAMEL does not explicitly model the consequence of each landslide type, the effect can be inferred based on landslide type (Keefer, 1984).

Structure

CAMEL is a regional-scale model for earthquake-induced landslide hazards created using fuzzy logic systems, a component of the Computing with Words (CW) modeling methodology. CW relates numbers and words, expressing algorithmic knowledge extracted from data, models, expert knowledge, and scientific literature. The "knowledge" represented in CAMEL was elicited from studies of occurrence of landslides during past earthquakes (Miles, 2004). Computing with Words enables CAMEL to be an understandable and adaptable model.

CAMEL implements fuzzy logic systems, which is a subset of CW. Fuzzy logic systems are an arrangement of IF-THEN rules relating input (antecedent) variables to output (consequent) variables. Computationally, these variables are a grouping of fuzzy sets, defined with respect to a finite numerical domain. Fuzzy sets such as these were first introduced by Zadeh (1965) and are an infinite-valued extension of Boolean sets; therefore, fuzzy sets recognize shades of gray (or "degrees of truth") between the

Boolean concepts of true and false. For a detailed description of the fuzzy logic system and functionality within CAMEL see Appendix A. The discussion below summaries the fuzzy logic system operating within CAMEL and illustrates the fundamental concepts based on the design guide of Berkan and Trubatch (1997).

The fuzzy logic system combines and utilizes: fuzzy sets, fuzzy variables, fuzzy logic operators, fuzzy rule-bases and consequent aggregation, fuzzy outputs and defuzzification. Fuzzy sets express degrees of belonging with zero (0) inferring not belonging and one (1.0) inferring belonging – to a particular category or classification. Fuzzy, or linguistic, variables are rules within fuzzy logic systems that are computable statements. The fuzzy rules are constructed with the fuzzy variables that have specific labels (predicates) or fuzzy values. Each fuzzy value relates membership functions (i.e., fuzzy sets), with a fuzzy variable as the antecedent and another fuzzy variable as the consequent; a simple single-input/single-output rule can be constructed as shown in Figure 8. Defuzzification means the scalar value is determined within the output variables.

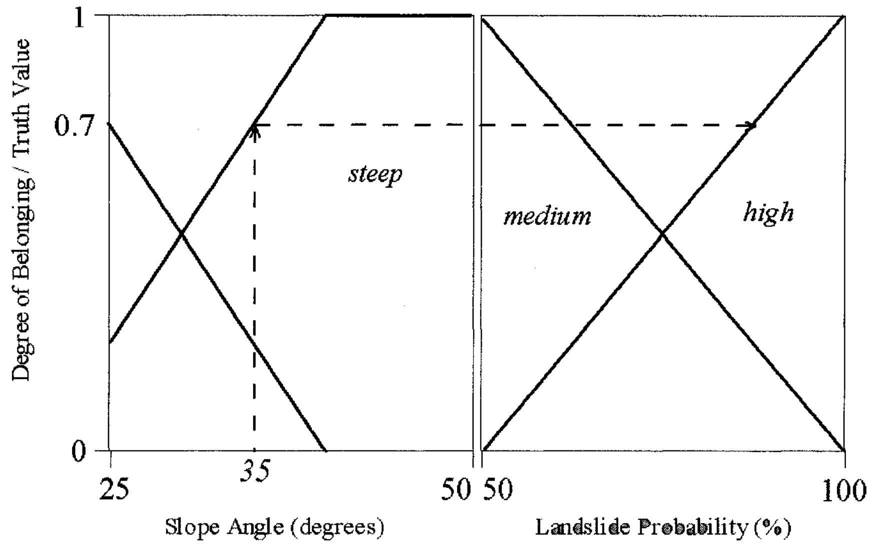


Figure 8. Example of the rule "IF Slope IS steep THEN Landslide Probability IS high" for fuzzy variables (Miles, 2004) (reprinted with permission from Miles)

Fuzzy logic operators are used to construct more complex rules for combining truth-values relating to fuzzy sets of different fuzzy variables (e.g., *Slope* and *Distance*). The three most common fuzzy operators are AND (minimum), OR (maximum), and PROD (product). The fuzzy logic rule-bases are fuzzy IF-THEN rules, with each rule mapping from any number of antecedent variables to the same consequent variable. An example introduced by Miles (2004), is shown in Table 7 below containing rule-bases of four rules. For the consequent label (fuzzy value) "high," there are two rules expressing separate relationships with respect to *Slope* and *Lithology*. Based on inputs to these two rules, it is possible to get two different truth-values for "*Landslide Probability* IS high". The two most common ways of dealing with this information are to either propagate the maximum truth-value (MAX) or take a bounded sum (BSUM). The MAX takes the maximum truth-value of all the truth-values computed for a particular output variable value. The BSUM is an aggregation operator that can't exceed 1.0 of all the truth values computed for a particular output fuzzy value. Table 6 lists an example rule-block containing four rules. Two rules (rules 3 and 4) output a "Landslide Hazard IS high." If the output truth-value for rule 3 is 0.7 and is 0.5 for rule 4 then, using the MAX operator to aggregate the truth values for "Landslide Hazard IS high", results in an aggregate truth value of 0.7 (the maximum of 0.5 and 0.7). The BSUM - the sum of the two truth-values for "Landslide Hazard IS high" - exceeds 1.0 and, therefore, results in a aggregate truth-value of 1.0.

Table 6. A four-rule fuzzy rule-base relating slope angle and fault distance to landslide hazard (Miles, 2004) (reprinted with permission from Miles).

1.	IF *Slope* IS shallow THEN *Landslide Probability* IS low
2.	IF *Slope* IS moderate AND *Distance* IS close THEN *Landslide Probability* IS medium
3.	IF *Slope* IS steep THEN *Landslide Probability* IS high
4.	IF *Lithology* IS landslide deposit THEN *Landslide Probability* IS high

The concepts of fuzzy logic systems were summarized by presenting a complete graphical example of fuzzy inference for a simple fuzzy IF-THEN rule-base in Miles (2004). Figure 9 presents the fuzzy rule-base of Table 6, showing the membership functions for each fuzzy variable as assumed above. Consider the input scenario of *Slope* = 35 degrees, *Distance* = 27 km, *Lithology* is landslide deposit to degree 0.5, similar to the examples above. The degree of support (DoS) is a "weight" between 0 and 1, which is multiplied to the output truth value. A DoS weight less than one reduces the influence of a particular rule. A final landslide probability of 88.5% is computed, assuming that all degree of support (DOS) are 1.0, bounded sum (BSUM) is used for consequent aggregation and Center of Maximum (CoM) method is used for defuzzification. The most common defuzzification method for modeling applications is called the Center of Maximum (CoM) method. The CoM method takes a weighted average of the output variable domain values, using as weights the truth value associated with the center of each output variable membership function.

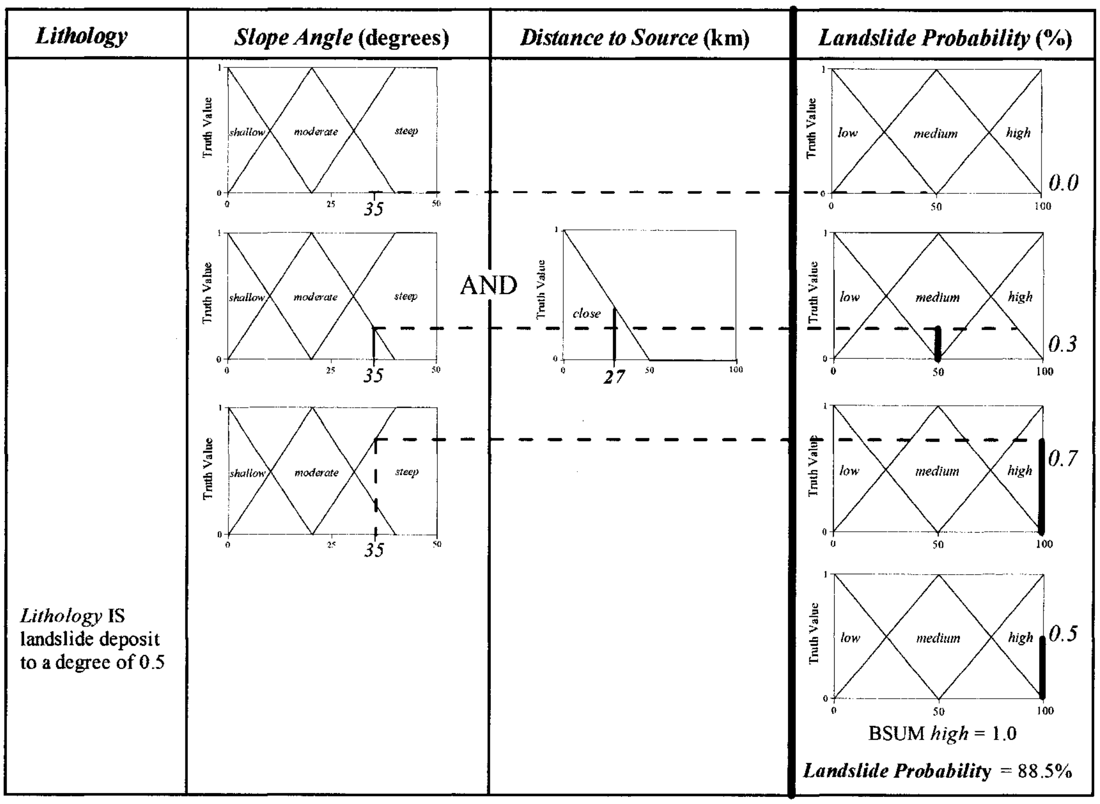


Figure 9. Complete example of fuzzy inference of a 4-variable, 4-rule fuzzy system (Table 7) for an input scenario of Slope = 35 degrees, Distance = 27 km, and Lithology IS landslide deposit to degree 0.5 (Miles, 2004) (reprinted with permission from Miles)

Modules

CAMEL utilizes two modules (landslide possibility and landslide hazard), each consisting of fuzzy IF-THEN rule-blocks (Fig. 10). These rule-blocks are used to determine the possibility and areal concentration of earthquake-induced landslides. The two modules separate possibility (Fig. 11) —referred to as "indicators"—from knowledge about relative hazard (Fig. 12) —referred to as "intensifiers"—for each landslide type. The possibility module uses "landscape attributes" as indicator knowledge to formalize the fuzzy thresholds, indicating whether each respective landslide type is possible. The hazard module determines the relative hazard, expressed as the number of landslides per square kilometer, for each possible landslide type.

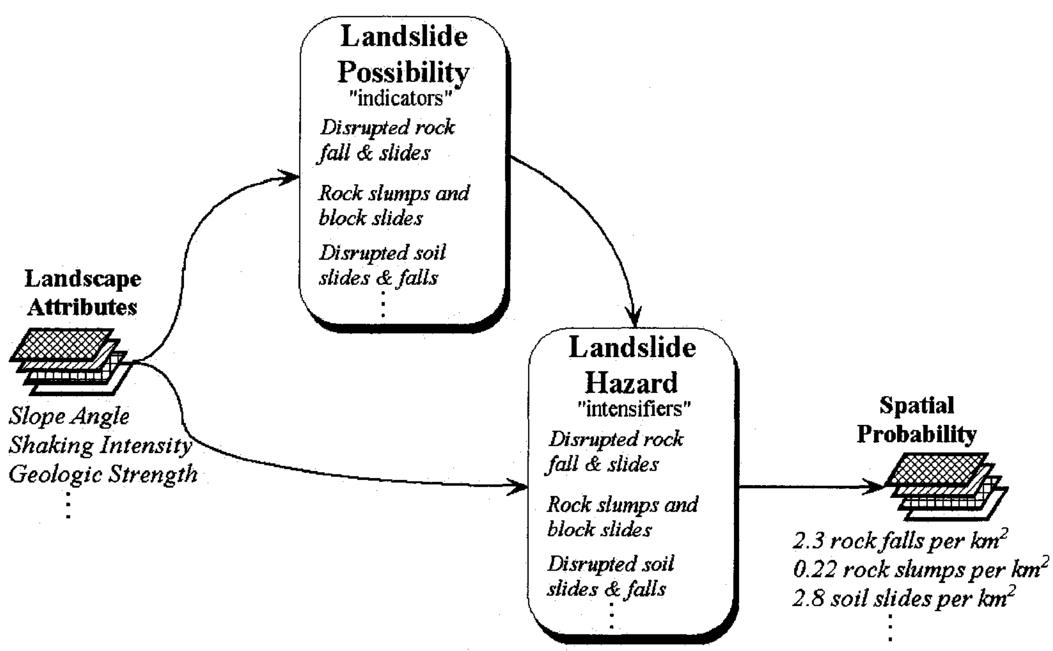


Figure 10. Two-module framework of CAMEL, including the possibility and hazard modules (Miles, 2004) (reprinted with permission from Miles)

The explanation below is to clarify a complex process without focusing too much on the technical aspects of CAMEL. The fuzzy system design was used to develop CAMEL in order to facilitate understanding between the two modules. Appendix A contains all of the antecedent fuzzy (linguistic) variables, defined graphically by presenting the membership functions for each fuzzy value with respect to the appropriate universe of discourse and consequent variable definitions presented in table form. The composition of each respective block of fuzzy IF-THEN rules is also described. Figure 11 below shows the "indicators" – shaking intensity, slope angle, moisture, terrain roughness, slope height, soil depth, and material type- that are processed through the fuzzy rule-blocks.

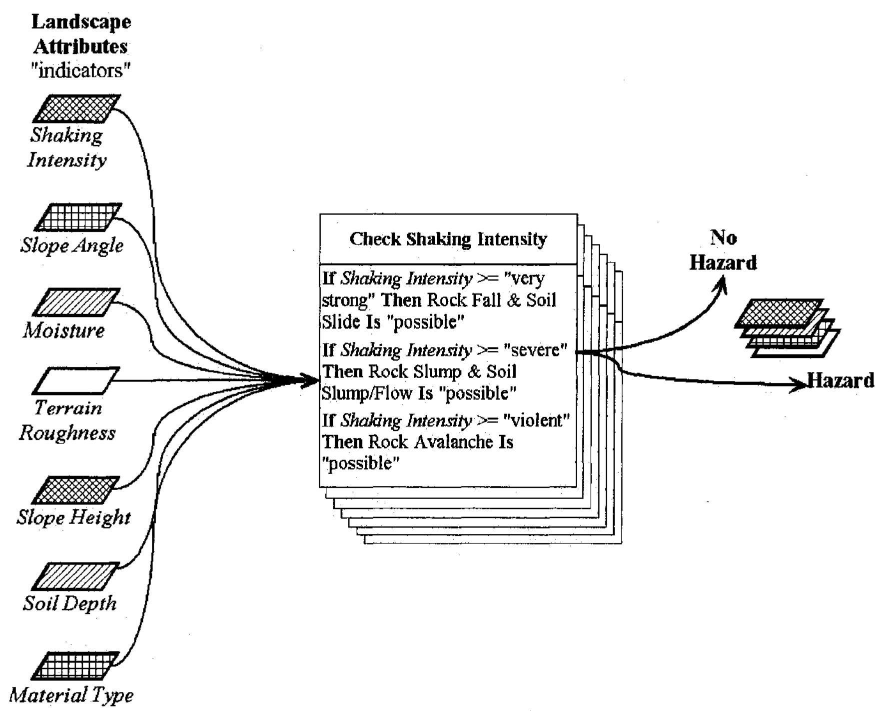


Figure 11. Possibility Module of CAMEL (Miles, 2004) (reprinted with permission from Miles)

Table 7 below lists the indicator variables that comprise the inputs of the possibility module of CAMEL. The variables are listed in the sequence in which CAMEL considers each indicator, though the specific sequence is arbitrary. The indicators show the quantitative units, minimum and maximum values, and the number and label of the fuzzy values for each variable. Each indicator is defined in Appendix A.

Table 7. CAMEL Input Variables—Indicators (Miles , 2004) (reprinted with permission from Miles)

Variable Name	Units	Min	Max	Fuzzy Value Labels
pTerrainRough	Slope of slope angle	0	40	planar rough
pShakeIntensity	Shakemap MMI	-1	12	**missing** greater_than_7 greater_than_8 greater_than_9
pSoilDepth	Meters	-1	10	**missing** shallow deep
pSlopeHeight	Meters	-1	300	**missing** low high
pMaterialType	(linguistic)	-	-	**missing** rock soil
pMoisture	Percent	0	100	more_than_moist about_saturated
pSlopeAngle	Degrees from the horizontal	0	90	between_5and40 between_15and40 greater_than5 greater_than_15 greater_than_25 greater_than_35

The hazard module (Fig. 12) contains two sub-modules – static susceptibility and seismic hazard – and has a data flow process similar to the Newmark displacement method. The fuzzy inference is executed on a set of intensifiers to compute ranges of landslide concentrations for each of the landslide types in CAMEL. The first sub-module – static susceptibility – is comprised of intensifiers independent of seismic shaking. The sub-module separates the intensifiers into whether they will be direct intensifiers or modifiers, based on landslide type. With certain landslides, for every antecedent increase of one fuzzy value in the static intensifiers (i.e., “low to medium”), the consequent increases by one fuzzy value. Modifiers contribute to static susceptibility by increasing or decreasing the susceptibility by no more than one fuzzy value.

The seismic hazard sub-module analyzes the static susceptibility sub-module and incorporates seismic shaking. The seismic hazard sub-module considers all possible combinations of static susceptibility and shaking intensity fuzzy values. Unlike the Newmark displacement, the analysis with CAMEL predicts landslide concentration (in number of landslides per square kilometer) for each landslide type.

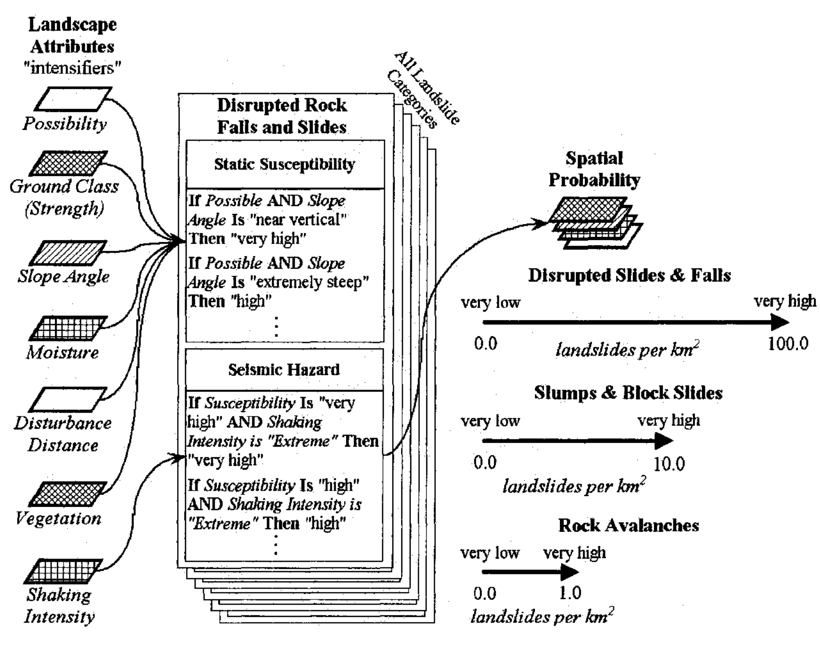


Figure 12. Landslide Hazard Module of CAMEL (Miles, 2004) (reprinted with permission from Miles)

Table 8 lists all of the input fuzzy variables representing the intensifier knowledge in CAMEL. As in the possibility module, each variable is defined with the quantitative units, minimum and maximum values, and the number and label of the fuzzy values for each variable. Whether a variable is utilized as an intensifier or modifier depends on the type of landslide being modeled. For example, *hMoisture* serves as an intensifier for Category II landslides, but as a modifier for Category I and III landslides. Appendix A evaluates in detail the hazard module intensifiers and these are summarized in Table 9.

Table 8. CAMEL input variables – intensifiers and modifiers (Miles, 2004) (reprinted with permission from Miles)

Variable Name	Unit	Min	Max	Fuzzy Value Labels
hDisturbanceDist	Meters	0	200	close far
hGroundClass	Relative (ratio) units	1	5	very_good good moderate poor very_poor
hMoisture	Percent	0	100	very_low low medium high very_high not_very_low
hShakeIntensity	ShakemapMMI	4	10	light moderate strong very_strong severe violent extreme
hSlopeAngle	Degrees from the horizontal	5	65	very_gradual gradual medium_gradual medium medium_steep steep very_steep extremely_steep nearl_vertical
hVegetation	Percent	0	100	sparse dense

Table 9. Hazard module intensifiers and modifiers (Miles, 2004) (reprinted with permission from Miles)

Landslide Type	Intensifiers	Modifiers
Rock Avalanches	*hGroundClass* *hSlopeAngle*	*hDisturbanceDist*
Disrupted Rock Slides and Falls	*hGroundClass* *hSlopeAngle*	*hDisturbanceDist* *hMoisture* *hVegetation*
Disrupted Soil Slides, Falls, and Avalanches	*hGroundClass* *hSlopeAngle*	*hDisturbanceDist* *hMoisture* *hVegetation*
Rock Slumps and Block Slides	*hGroundClass* *hSlopeAngle* *hMoisture*	*hDisturbanceDist* *hVegetation*
Soil Slumps and Block Slides	*hGroundClass* *hSlopeAngle* *hMoisture*	*hDisturbanceDist* *hVegetation*
Rapid Soil Flows	*hGroundClass* *hSlopeAngle*	*hDisturbanceDist* *hMoisture* *hVegetation*

Layers

CAMEL operates through a GIS-based program such as ArcGIS 9.0. CAMEL, like a typical ArcGIS map, contains a number of layers (with or without connected databases) that stack atop of each other. When implementing CAMEL, the nine layers typically used are:

1. Slope Angle
2. Terrain Roughness

3. Slope Height
4. Material Type
5. Disturbance Distance
6. Soil Depth
7. Moisture
8. Vegetation
9. Shake Intensity

Of the nine layers, only the slope is technically necessary to operate the model. Three of the nine layers (slope, slope height, and terrain roughness) are derived from a Digital Elevation Model (DEM) (Fig. 13) of the San Francisco Bay Area. This means that these layers are only as accurate and precise as the DEM itself. The model will only operate when all nine layers are of the same resolution and since the DEM is 10 meters, all other layers are correlated to this value. The shake intensity map covering the San Francisco Bay Area has the smallest area; therefore, all layers within the GIS were clipped to its size creating nine layers of identical resolution and shape.

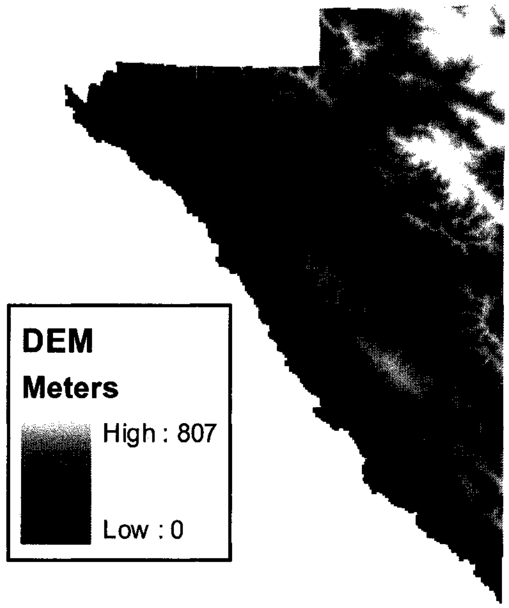


Figure 13. Example of a Digital Elevation Model (DEM)

1. Slope Angle

CAMEL separates the possibility of certain types of landslides by the slope angle as previously defined by Keefer and other researchers. Table 10 below summarizes the range of slopes (in degrees) necessary for particular types of landslides to initiate. The majority of flows in the data set of Keefer (1984) are greater than 5 degrees. Currently, the possibility for soil avalanches is over-predicted by CAMEL because the general minimum slope angle for this landslide type is 25 degrees. Disrupted soil slides are very common (Keefer, 1984); so the model is designed to reflect this possibility. Knowledge about soil block slides is applied to both soil block slides and soil slumps. Additionally, a slope angle maximum of 40 degrees for the Category II landslides (rock slumps and block slides, soil slumps and block slides) is based on work by Hansen and Franks (1991) and Cruden and Varnes (1996).

Table 10. Minimum slope angles for each type of landslide modeled by CAMEL (Miles, 2004) (reprinted with permission from Miles)

Landslide Type	**Minimum Slope Angle (degrees)**		
	Keefer (1984)	Rodriguez et al. (1999)	Hancox et al. (2002)
Disrupted rock falls and rock slides	35-40	35	40
Disrupted soil slides/soil falls	15/40	55	25-35
Rock avalanches	25	n/a	25-35
Rock slumps and rock block slides	15	15	15
Soil slumps and soil block slides	5-10	8	15
Rapid soil flows	2.3	0	2

The DEM was clipped from a larger, statewide figure. Although 3 meter DEMs exist for parts of the San Francisco Bay Area, they did not sufficiently cover the area of interest for this project. The ArcGIS program provides a means of creating slope angle maps from the DEMs through the spatial analyst tool, "surface analysis" (Fig. 14).

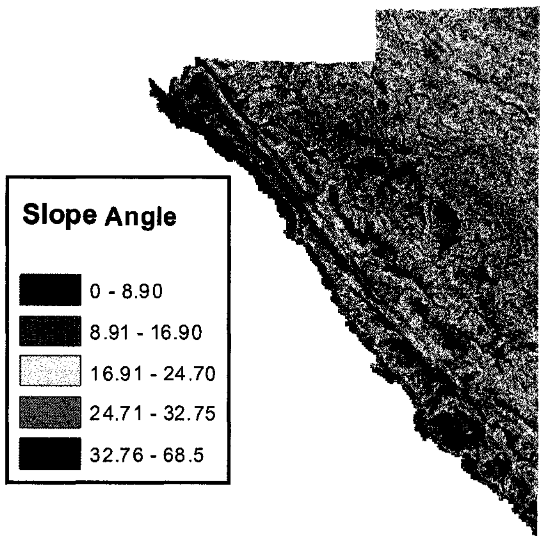


Figure 14. Example of a derived slope angle layer map

2. Terrain Roughness

The terrain roughness is a measure of the convexity/concavity of the slope of the San Francisco Bay Area. A recent study by Liao et al. (2002) found that a variable they referred to as "terrain roughness" correlated exceptionally well with the occurrence of landslides from the 1999 Chi-Chi, Taiwan earthquake (Miles, 2004). Terrain roughness is simply slope curvature in profile. In other words, it is the second derivative of elevation in the down-slope direction, with all calculations done in degrees. The layer is attained by simply rerunning the surface analysis under the spatial analyst tool on the slope angle. The redder the hue, or greater the value, the rougher (less planar) the slopes are in Figure 15.

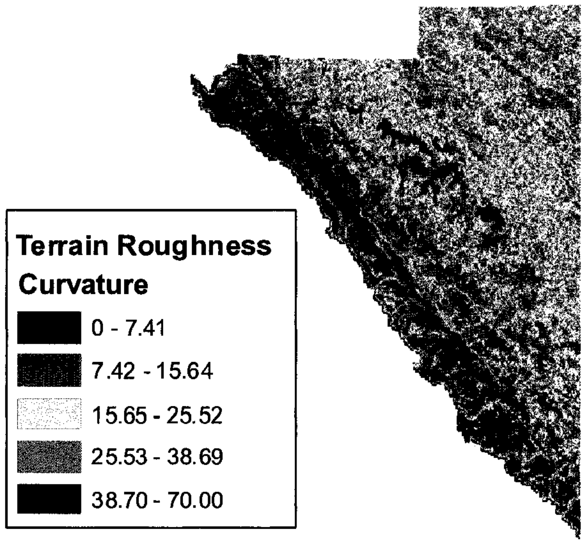


Figure 15. Example of terrain roughness layer map

3. Slope Height

Slope height is a layer of the possibility module; accounting for specific criteria for the different types of landsliding. According to Keefer (1984), the occurrence of rock avalanches requires a slope height of equal to or greater than 150 meters (Keefer, 1993).

As with the slope angle, the slope height is directly derived from the DEM. To calculate the slope height, elevations values in a 500 m radius circle surrounding each individual pixel in the study area were found. These values were then subtracted from the elevation of pixel at the center of that particular cirlce (Fig. 16).

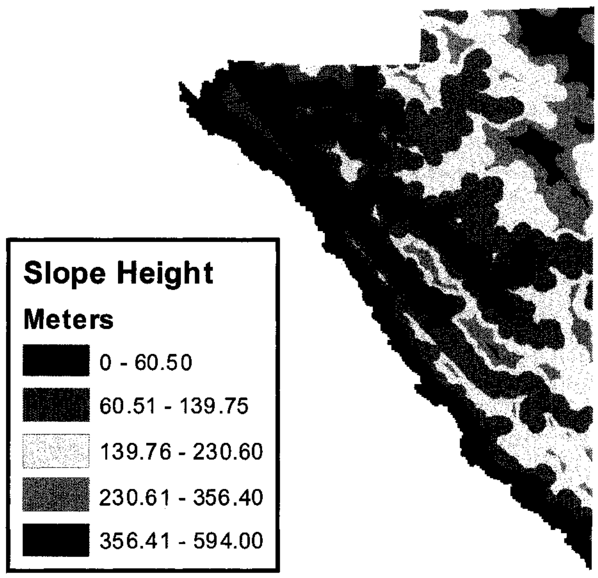


Figure 16. Example of slope height layer map

4. Material Type

CAMEL utilizes qualitative interpretations of geologic materials when determining the locations and concentrations of earthquake-induced landslides. Unlike the aforementioned layers, which were derived using ArcGIS from a base DEM, the material type layer was created using knowledge and interpretation of the formations, assemblages, and general distribution of lithologies in the San Francisco Bay Area. Until recently, the geologic maps of the Bay Area were split along geographic lines. At the same time the CAMEL program was being assembled, a separate department within the USGS was combining the individual geologic maps into a single GIS file for the entire Bay Area. At the time the database was being implemented for CAMEL, it had not been purged of the multitudes of names for similar formations/deposits; therefore, over 1300 polygons needed to be defined. A link to the final geologic map can be found at http://pubs.usgs.gov/sim/2006/2918/.

The material type value is selected from a scale between 1 and 5. One (1) indicates the strongest material and five (5) the weakest. For examples, the "strongest" material would be intact, cohesive, unweathered granite with no distinct cleavage planes and the weakest would consist of Quaternary landslide material. In CAMEL, material strength correlates with the susceptibility of a material to move during a seismic event. Based upon information elicited from Keefer (2000) (Fig. 17), Hancox et al. (2002) (Table 11), Ellen and Wentworth (1995), personal communications with David Keefer, and knowledge about specific formations and types of materials, each geologic unit (named p-type within CAMEL) on the geologic map and in the connected ArcGIS database was given a value between 1 and 5 (mclass) (Appendix B).

This method is equal to, and in many cases, superior to that typically used in the Newmark analysis. Most researchers use "book values" and expert knowledge or compile shear strength test data from various sources such as county engineering reports or limited field-testing when implementing a Newmark-based hazard zonation approach (Miles, 2004). As previously mentioned, Keefer (2000) determined landslide concentrations resulting from the Loma Prieta earthquake did not correlate well with engineering estimates specifically compiled for regional application of Newmark's method by McCrink and Real (1996). However, these concentrations did correlate with linguistic descriptions of the lithology, which can be communicated within CAMEL on the scale between 1 and 5. For example descriptions such as: "unconsolidated and semi-consolidated sediments"; "weakly cemented sandstones and siltstones"; "moderately cemented mudstones, siltstones, and shales"; "moderately cemented sandstones"; and, "well-indurated igneous and metamorphic rocks" can be individualized for a particular formation, improving the regional applicability of the application.

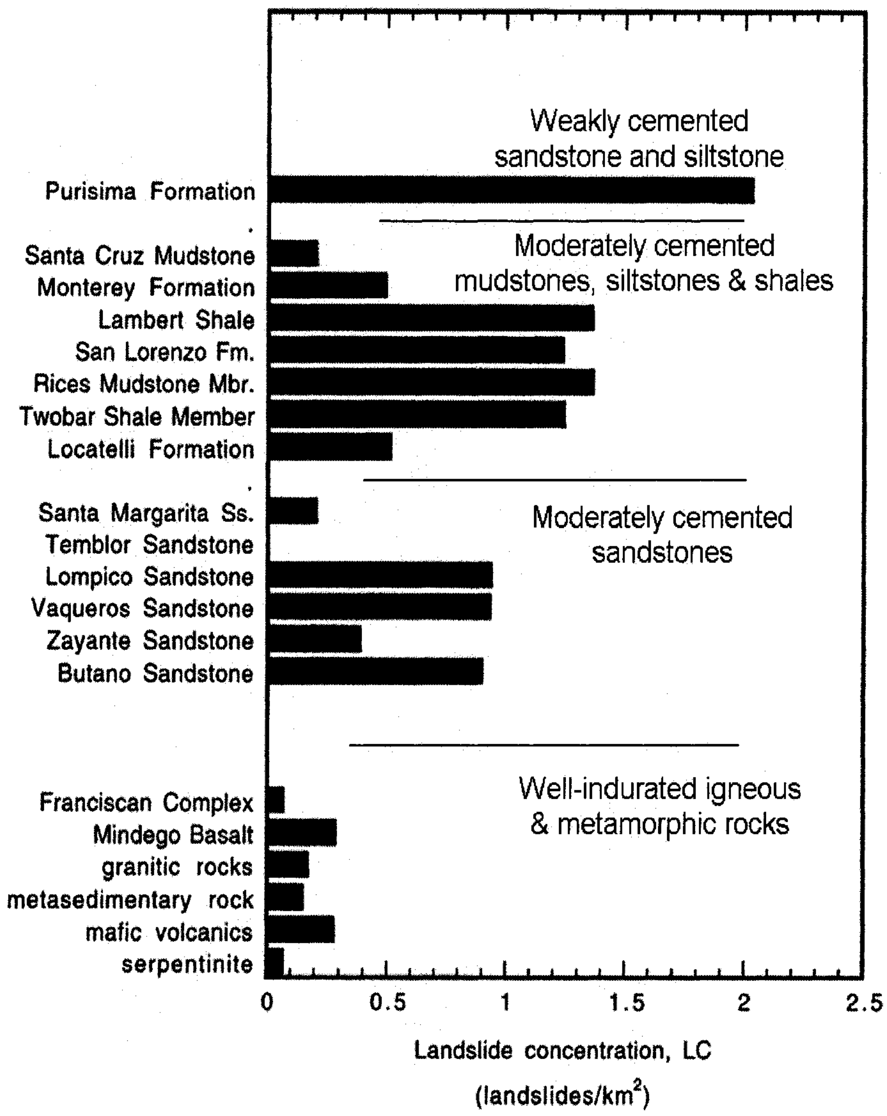


Figure 17. Landslide Concentrations for several formations during the 1989 Loma Prieta Earthquake (Keefer, 2000) (reprinted with permission from Keefer)

Table 11. Ground classes of Hancox et al. (2002) (reprinted with permission from Hancox)

Class I

(a) Bedrock - hard to firm rocks, relatively massive (unbedded), both widely and closely jointed, indurated greywacke and granitic rocks, moderately weathered to fresh, with thin (< 1-2 m) surficial colluvial materials, on gentle to moderate slopes (15-30°). Also, firm older alluvial deposits (gravels) forming high terraces (not terrace edges). This class is the benchmark against which other ground classes can be compared.

(b) Supported cut slopes in bedrock; engineered fills on firm ground.

Landslide susceptibility	*Low - very low*

Class II

Bedrock - well bedded, slightly to moderately weathered Tertiary sandstone, mudstone, and limestone dipping down slope on gentle to moderate slopes (15-30° dip slopes), with thin regolith and surficial deposits. Also firm to stiff soils.

Landslide susceptibility:	*Moderate-high*
Average change in MM intensity from Class I:	*+ 0.5 - 1*

Class III

Bedrock - well jointed indurated greywacke and granitic rocks, moderately to highly weathered, with thick (>5 m) regolith and colluvium on high, steep to very steep (say 35-50°) slopes, and on high narrow ridges (near and far field). Also low gravel banks and terrace edges, scree deposits, and slopes and cuts formed in loose unconsolidated deposits.

Landslide susceptibility:	*High-Very High*
Average change in MM intensity from Class I:	*+ 1 - 1.5*

Class IV

(a) Areas of very steep (>45°) natural slopes (such as cliffs, escarpments, gullies, and gorges) in hard, jointed rocks, weak Tertiary rocks, and also weakly-cemented Quaternary deposits (loess, pumice).

(b) Unsupported high (>3-6 m), very steep (say >60°) cuts and excavations in harder bedrock and soft rocks, especially those cuts capped with 1-3 m of soils and regolith deposits, and not designed to withstand the effects of seismic shaking.

Landslide susceptibility:	*High-very high*
Average change in MM intensity from Class I:	*+ 1 - 2*

Class V

Loose, saturated, unconsolidated, fine-grained, alluvial, estuarine and marine deposits (fine sand, silt), and other soft sediments, non-engineered fills and reclamations on flat, low-lying terrain and gentle slopes (<10°).

Landslide susceptibility:	*High- very high*
Average change in MM intensity from Class I - Near field [1]:	*+ 0.5 - 1*
Low frequency shaking - Far field [1] (> M 7.2 earthquakes):	*+ 1 – 3*

Once each of the p-types had a corresponding "mclass" number, the attribute table was recombined with the geologic map (Fig. 18). The expressed value displayed on the map, rather than the name of the formation (i.e. Qls), was the mclass number.

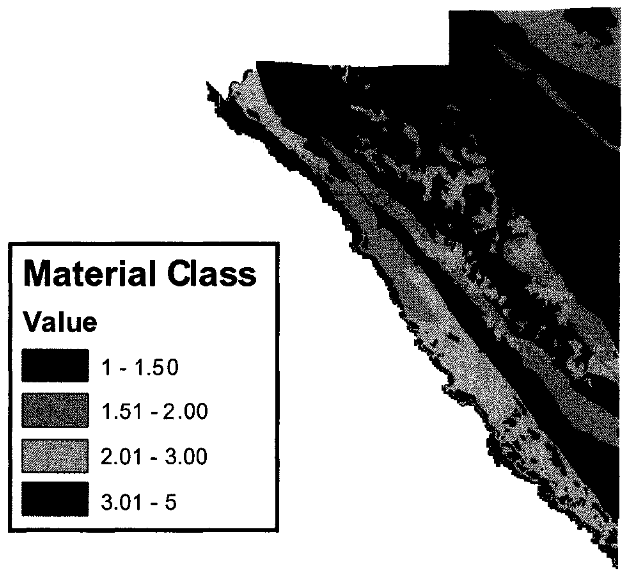


Figure 18. Example of material class layer map

5. Disturbance Distance

The Disturbance Distance represents morphological features contributing to slope failure, such as toe erosion by an undercutting stream or an over-steepened road cut (Cruden and Varnes, 1998). The disturbance distance is the distance (in meters) between a slope and a linear disturbance feature (i.e. stream or road). The disturbance distance relation in CAMEL is a logarithmic curve, dramatically decreasing its impact with increasing distance from the slope.

The disturbance distance layer was attained by manipulation of topographic base maps. This was done by overlaying the road layer and stream layer for the area, rasterizing each to 10 m resolution, and then running the nearest distance calculation in Spatial Analyst within ArcGIS (Fig. 19).

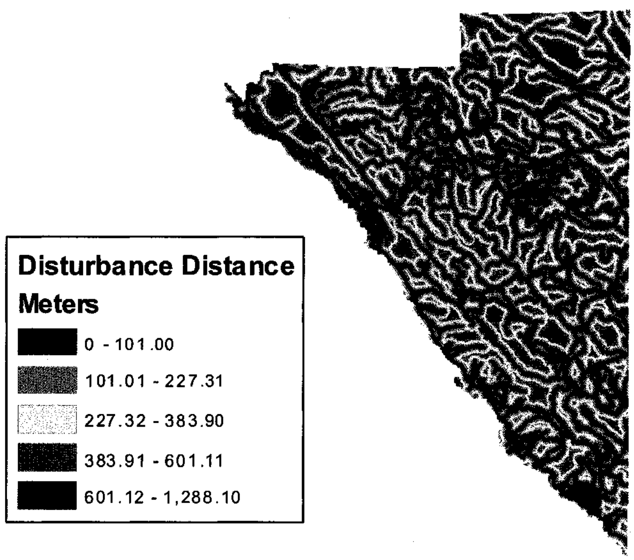


Figure 19. Example of disturbance distance layer map

6. Soil Depth

The Soil Depth represents the mantle of unconsolidated material atop the bedrock geology. Knowledge of the impact of the depth of soils on landsliding is based on Keefer (1984) and Bommer and Rodriguez (2002). Because of a lack of attainable GIS information regarding variable soil depths around the San Francisco Bay Area, a constant depth of 4 m was selected. Less than 4 meters is the threshold depth at which the

CAMEL excludes deep-seated landslides from the possibility module; furthermore, the inference is only placed on the soil slump type of landslide. By selecting this depth, no landslide types were excluded based solely on the depth of soil.

The depth of soil layer was created in ArcGIS by clipping a raster of the area of interest from the limiting layer, in this case the shake intensity map. Once the boundary was identified, the entire raster was given a value of 4 by using the raster calculator within the ArcGIS program (Fig. 20).

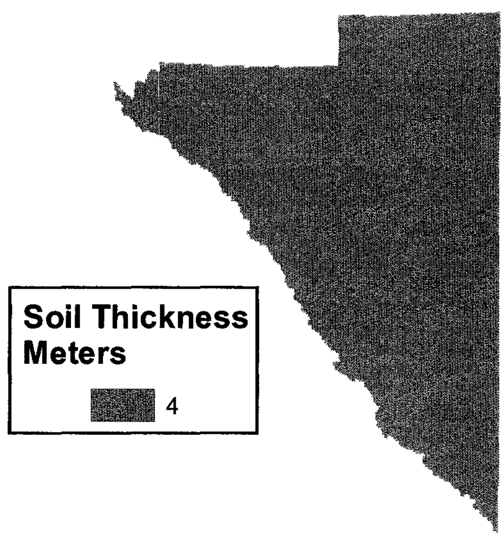


Figure 20. Example of soil thickness layer map

7. Moisture

Moisture represents a measure of the groundwater in the analysis layer. It is conceptually the ratio of the ground water height over the depth of the ground layer under analysis, multiplied by 100% (this is the same definition as the m-value used in most limit equilibrium slope stability models, such as the infinite slope model) (Miles, 2004).

The moisture percentage selected, for instance "more_than_moist" in the fuzzy logic lexicon, relates to the Category II landslides previously defined by Keefer (1984). A higher moisture value permits landslides requiring a greater moisture percentage to be possible, i.e. rapid soil flows. Conversely, landslide types such as rock falls, rock avalanches, and soil slides do not require minimum soil moisture to be capable of movement during a seismic event.

Two maps were generated for each type of landslide (except soil flows) using two different soil moisture values. Layers with values of 12.5% and 62.5% were created in a fashion similar to soil thickness, using the raster calculator. The value 12.5% represents a lower percentage of saturation of the material while 62.5% is considered near saturation (Fig. 21).

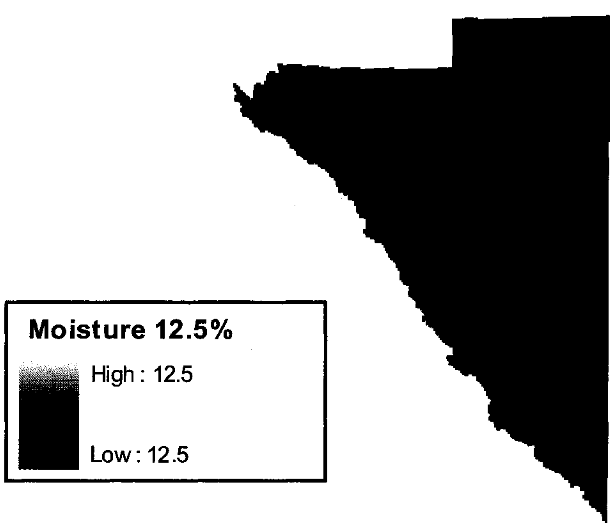


Figure 21. Example of soil moisture layer map

8. Vegetation

Very little information is available regarding the impact of vegetation percentages on earthquake-induced landslides beyond the decision tree for assessing disrupted rock fall and slide susceptibility of Keefer (1993). For this reason a simple definition was assumed. A publicly accessible GIS layer provided by California multi-source landcover data, found at the website http://gis.ca.gov/meta.epl?oid=5291, was used. This categorized coverage percentages rather than distinguishing between vegetation types (Fig. 22); 0 percent denotes urban areas and 100 percent indicates heavily vegetated areas.

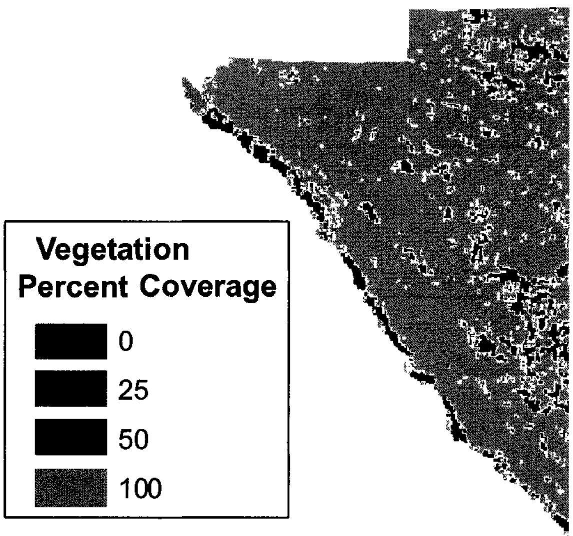


Figure 22. Example of vegetation coverage layer map

9. Shake Intensity

The Shake Intensity layer represents intensifier knowledge about earthquake shaking intensity. The layer is the defining shape for our area of interest because it is the most limiting in geographic size. The variable is simply a fuzzy translation of the MMI scale (considering the values between and including 4 and 10). No values less than 4 are defined, since earthquake-induced landslides are seldom generated at lower intensities. In turn, no values greater than 10 are defined because the shake map does not provide these values and little data exist on landslides related to such large intensities. The layer used for this project was the 1906 ShakeMap of the San Francisco Bay Area produced by the USGS (Fig. 23; Boatwright and Bundock 2005). A link to these data can be found at http://quake.wr.usgs.gov/research/strongmotion/effects/1906/.

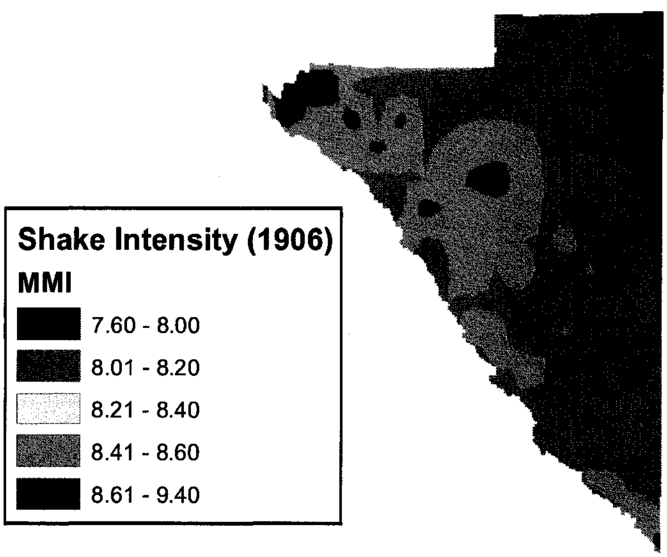


Figure 23. Example of shake intensity map layer

The combined layers within the ArcGIS/CAMEL model are shown in Figure 24.

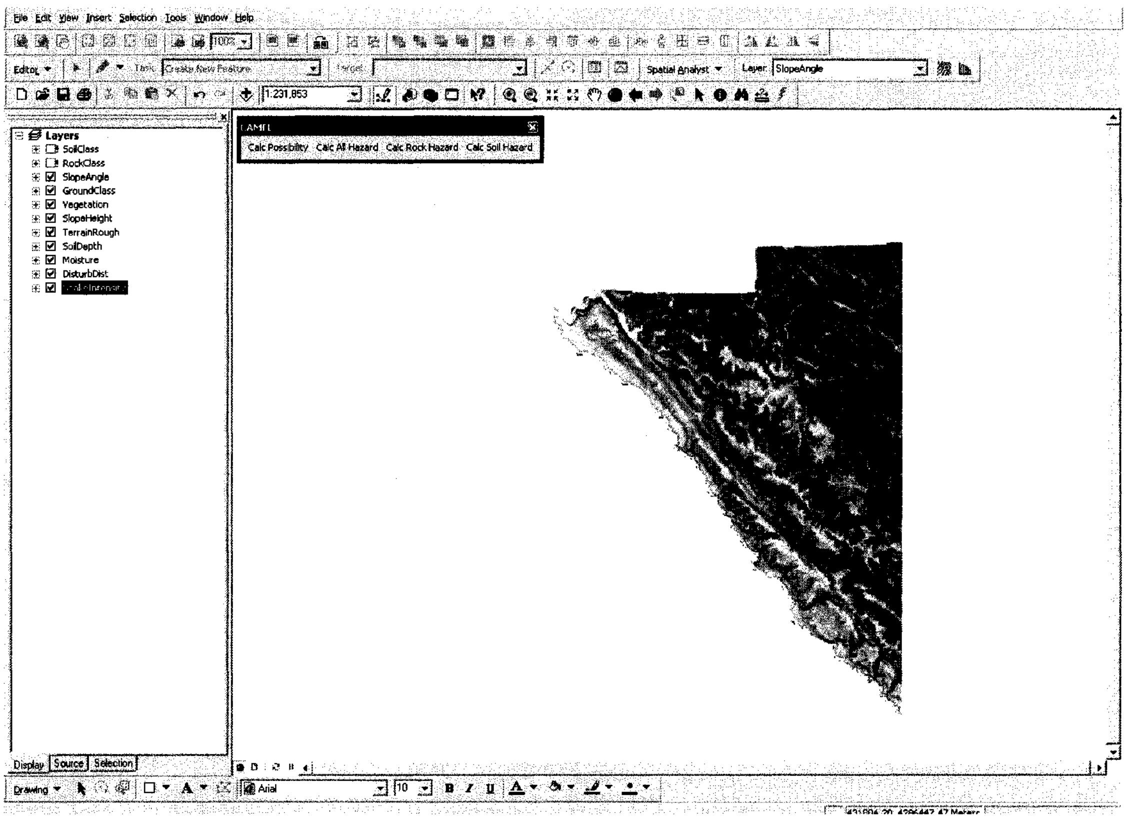


Figure 24. Stacked layers in the CAMEL model awaiting processing

MAPS

Output

CAMEL produced 11 maps for earthquake-induced landsliding for the 1906 ShakeMap, a wet and a dry scenario for each of the six possible outputs (except rapid soil flow, only wet). Detailed maps in PDF format are provided on the CD in the back of this thesis. The maps are listed as Plates 1 through 11. Each type of landslide shown on the corresponding maps is listed below:

- Plate 1. Rock Avalanches – Dry
- Plate 2. Rock Avalanches -- Wet
- Plate 3. Disrupted Rock Slides and Rock Falls -- Dry
- Plate 4. Disrupted Rock Slides and Rock Falls -- Wet
- Plate 5. Rock Slumps and Rock Block Slides -- Dry
- Plate 6. Rock Slumps and Rock Block Slides -- Wet
- Plate 7. Disrupted Soil Slides, Soil Falls, and Soil Avalanches -- Dry
- Plate 8. Disrupted Soil Slides, Soil Falls, and Soil Avalanches -- Wet
- Plate 9. Rapid Soil Flow -- Wet
- Plate 10. Soil Slumps and Soil Block Slides -- Dry
- Plate 11. Soil Slumps and Soil Block Slides – Wet

CAMEL was constructed with a framework based on the range of the historical abundance (from Table 1) and concentrations of landslide types described in Keefer (1984). For instance, a "very high" concentration of rock falls is a considerably greater value than a "very high" concentration of rock avalanches, as discussed previously in this report. According to Miles (2004), because the best information available was for disrupted rock falls and disrupted rock slides, the framework was based on the quantitative knowledge available for this type and then scaled with the order of magnitude variations to describe the other landslide types with one exception. Rock avalanches are three magnitudes less common than rock falls and disrupted rock slides; however, the maximum rock avalanche concentration of 0.1 ls/km^2 was considered too low and was assigned a maximum of 1 ls/km^2, which is conversely an extremely high concentration.

The concentration ranges used in CAMEL are in a natural log scale. The natural log scale reduces the impact that would result from an arithmetic scale. An arithmetic scale would cause lower concentrations (more likely to occur) to be clustered together, giving too much influence to the higher fuzzy values during the defuzzification process. With the natural log scale, the peak of each membership function is located at equal intervals. The geometric increase between values is 3.16 landslides/km^2, correlating with the four-fold increase between the concentration categories (Table 2) of Keefer (1993). Although landslide concentration output values will always be greater than zero when using a natural log scale, from an implementation perspective, if the possibility module is zero, the reported landslide concentration is also zero. The concentration ranges for the CAMEL maps are:

- Rock Avalanches = 0 to 1 number of landslides/km^2
- Disrupted Rock Slides and Rock Falls = 0 to 100 number of landslides/km^2
- Rock Slumps and Rock Block Slides = 0 to 10 number of landslides/km^2
- Disrupted Soil Slides, Soil Falls, and Soil Avalanches = 0 to 100 number of landslides/km^2
- Rapid Soil Flows = 0 to 10 number of landslides/km^2
- Soil Slumps and Soil Block Slides = 0 to 10 number of landslides/km^2

The natural logarithmic scale for landslide concentrations on the maps is separated into five ranges. Each of the ranges has an associated fuzzy value. For example, disrupted rock slides and falls are:

a. 0 – 0.1 number of landslides/km^2 and "very low"

b. 0.1 – 1.19 number of landslides/km^2 and "low"

c. 1.19 – 3.161 number of landslides/km^2 and "medium"

d. 3.161 – 17.8 number of landslides/km^2 and "high"

e. 17.8 – 100 number of landslides/km^2 and "very low"

Results

CAMEL modeled landslides throughout the greater Bay Area. In general, the highest concentrations of landslides (variable by category and type) were located in the Santa Cruz Mountain Range (in particular, the Laurel and Loma Prieta quadrangles), along the coast, and in Sonoma County (within the North Coast Range). The landslide concentrations trend linearly, coincident with the large regional faults in the Bay Area, but are particularly focused along the traces of the San Andreas Fault. These areas are acutely susceptible to landsliding during an earthquake because:

1. They have some of the most considerable topographic relief in the Bay Area, resulting in significant slope heights and steep slope angles;
2. The areas are close to or along traces of the San Andreas Fault, resulting in intense ground shaking; and,
3. The local lithologies in these locations primarily consist of Quaternary landslide deposits (Qls) and the Purisima Formation (Tp) (in the Santa Cruz Mountains), weakly consolidated marine terrace and coastal deposits (along the coast), or the Wilson Grove Formation (in the North Coast Ranges). Each of these formations are considered highly susceptible lithologic units (4.5 to 5 on the mclass rating) relating to slope instability in the Bay Area.

During the 1989 Loma Prieta earthquake the Santa Cruz Mountains and nearby coastal cliffs were regions of extensive landsliding (Keefer 1998; 2000). The Santa Cruz Mountains, especially in seismic scenarios involving the San Andreas Fault, historically has produced a large volume of landsliding, observed during both the 1906 and 1989 events (Lawson 1908; Youd and Hoose, 1978; Keefer, 1998). The figures below highlight areas of interest and/or high concentrations of a particular category.

Category I

Rock Avalanches Rock avalanches are primarily a function of slope inclinations, occurring only on very steep slopes with possible free fall and in susceptible geologic lithology. The highest rock avalanche concentrations (0.316 to 1 landslides/km^2) were modeled along the assumed trace of the San Andreas Fault between the Loma Prieta and Laurel quadrangles (Fig. 25). According to Miles (2004), the concentration of rock avalanches modeled is over predicted by about an order of magnitude (maximum expected concentration 0.1 landslides/km^2 rather than 1 landslides/km^2) in the San Francisco Bay Area. Because the model is intended for universal use the model outputs correlate with worldwide occurrence, not solely the landslide types generated by local earthquakes.

The majority of the Bay Area is not conceptually susceptible to rock avalanches (0 to 0.001 landslides/km^2) because most slope angles are less than 25 degrees. The second most frequently occurring concentration of rock avalanches was between 0.001 and 0.032 landslides/km^2, located throughout the Coast Ranges. The highest concentration was modeled to be between 0.1 and 0.316 landslides/km^2 located near the border of the Loma Prieta and Laurel quadrangles. The geologic materials consist of Quaternary landslide deposits and the Purisima Formation along the trace of the San Andreas Fault in this area (Fig. 25).

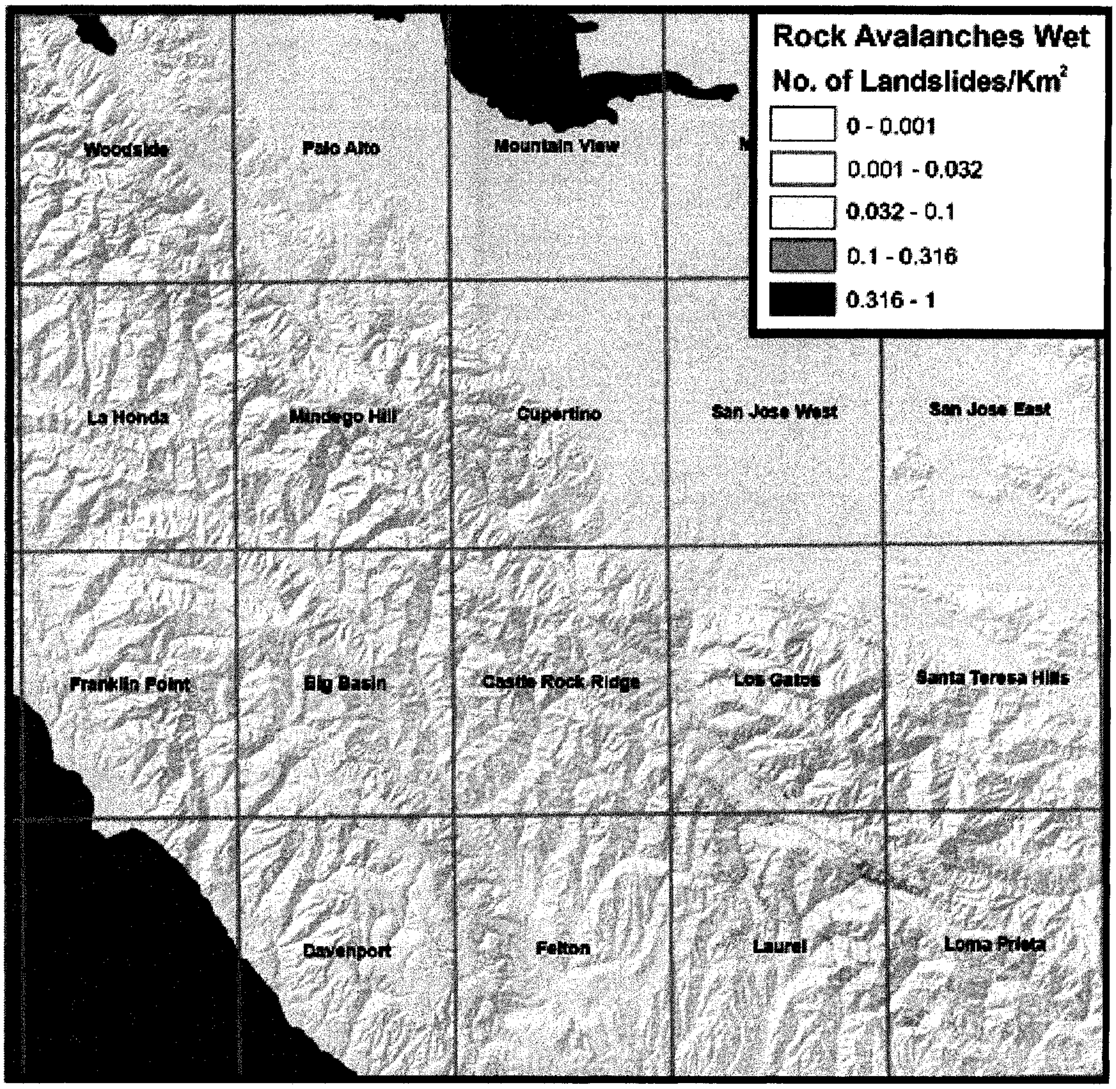


Figure 25. CAMEL results for rock avalanches highlighting areas of greatest concentration and/or areas of interest

Rock Falls and Disrupted Rock Slides The maximum value (100 landslides/km^2) for rock falls and disrupted rock slides was based on research by Parise and Jibson (2000) for the 1994 Northridge, CA earthquake, which determined concentrations of about 74 landslides/km^2. The highest category in the rock fall decision tree of Keefer (1993) was greater than 16 landslides/km^2. Though rock fall and disrupted rock slide concentrations may be higher elsewhere, within the San Francisco Bay Area the geomorphology results in landslide concentrations more in line with Keefer's (1993) findings (Fig. 26).

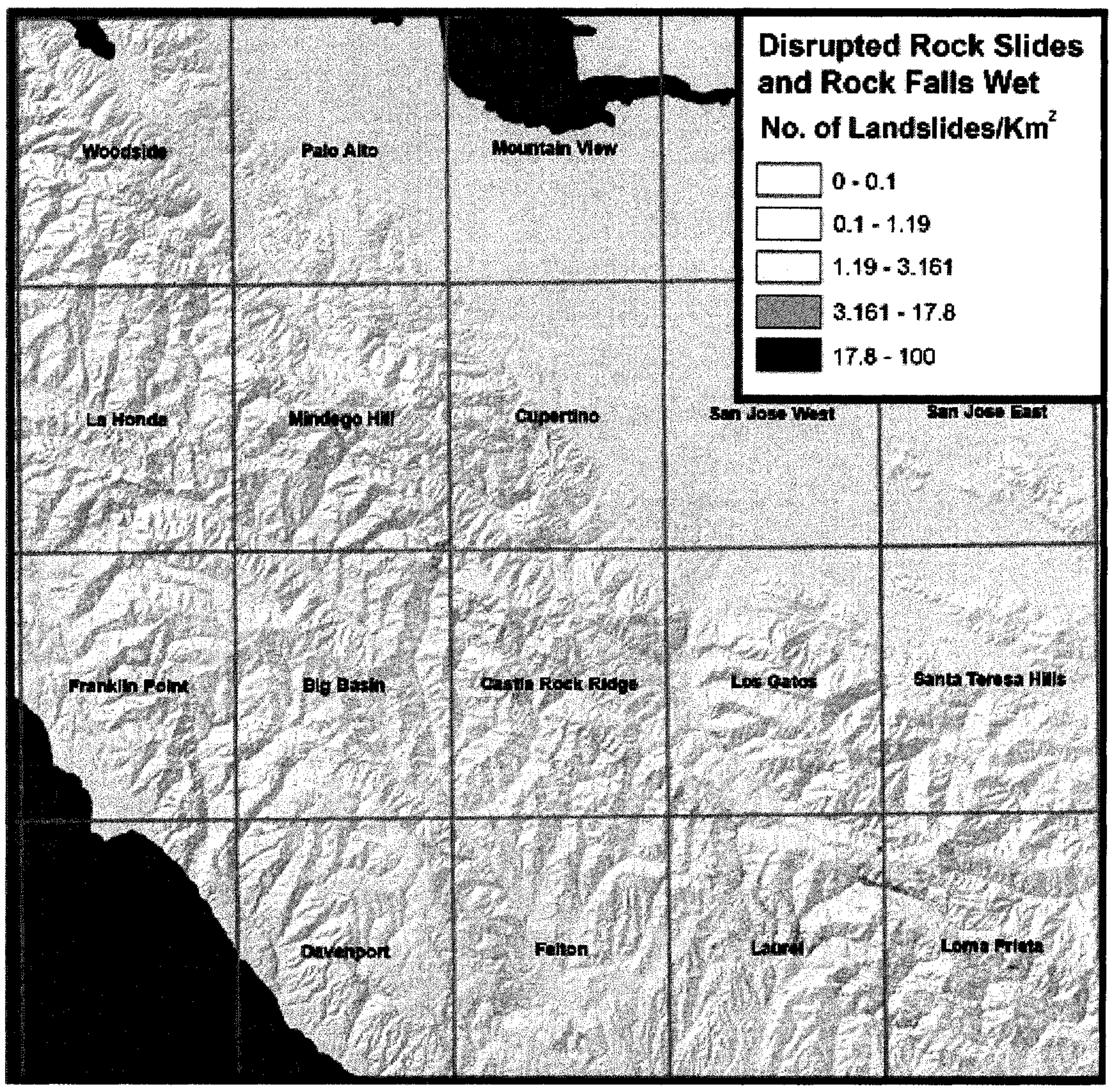


Figure 26. CAMEL results for disrupted rock slides and rock falls highlighting areas of greatest concentration and/or areas of interest

Because of the greater range in concentration and large amount of unsusceptible areas for rock falls and disrupted rock slides, distinct patterns are more difficult to discern than for rock avalanches. Bands of rock falls and disrupted rock slides are coincident with lithologic variations, along traces of the San Andreas Fault, and along the coast (in particular, south of San Francisco and in the Marin Headlands). Though the landslide concentration of disrupted rock slides and rock falls may not appear more prominent than for rock avalanches, the scale is two orders of magnitude greater. The highest concentration of the rock avalanches may consist of 1 landslide in a particular square kilometer while the rock falls and disrupted rock slides would be 100. Most of the Bay Area is not modeled as conceptually susceptible to disrupted rock slides and rock falls because the estimated minimum slope angle for occurrence is 35 degrees. This is evident in the Coast Ranges. Rock avalanches are modeled as feasible throughout and disrupted rock falls and rock slides are located in notably smaller zones. But where the disrupted rock falls and rock slides are modeled as conceptually feasible, concentration ranges are higher in both occurrence (between 1.19 – 3.161 and 3.161 – 17.8) with fuzzy value of "medium" and "high".

Soil Falls, Disrupted Soil Slides, and Soil Avalanches Figure 27 below presents the map of predicted concentrations of disrupted soil slides, falls, and avalanches in the same area as the rock avalanches and disrupted rock slides and falls. The landslide concentration range is from 0 – 100 landslides/km^2 and shows a strong linear affinity with the San Andreas Fault. The map contains a relatively small amount of zero landslide concentration in the mountainous areas, in contrast to the disrupted rock slides and falls map. This is a result of the influence of pSlopeAngle, with a fuzzy threshold of 15 degrees for full possibility.

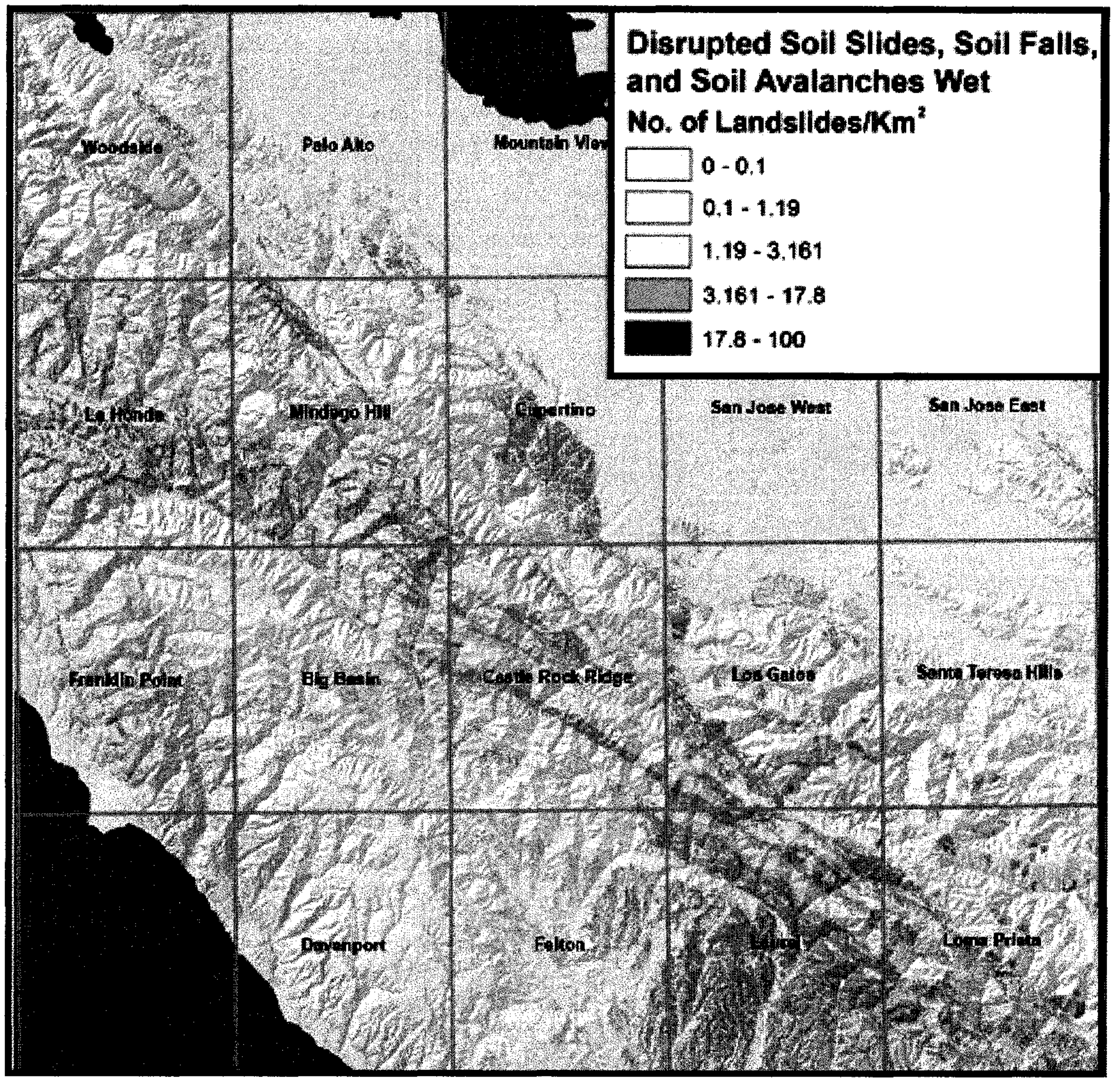


Figure 27. CAMEL results for soil falls and disrupted slides highlighting areas of greatest concentration and/or areas of interest

Soil falls, disrupted soil slides, and soil avalanches are modeled in at least "low" concentrations essentially everywhere with sufficient slope steepness. The concentrations are generally highest in the Wilson Grove Formation in the North Coast

Range, along the coast south of San Francisco and in the Marin Headlands area, and in the Loma Prieta and Laurel quadrangles (Plates 7 and 8). The concentrations dissipate to the east away from the trace of the San Andreas Fault, with generally lesser concentration values observed in the East Bay. The "high" concentration, trending linearly NW-SE, of predicted landslides in the Oakland East quadrangle is near the trace of the Hayward Fault within susceptible geologic materials.

Category II

Figures 28 and 29 below highlight the areas surrounding the City of San Francisco and present the impact of increasing the moisture percentage on Category II type landslides.

Rock Block Slides and Rock Slumps Rock block slides and rock slumps range between 0 and 10 landslides/km^2 and necessitate a minimum slope inclination of 15 degrees to "activate". CAMEL was developed to accentuate the impact of increasing moisture saturation on the concentration of landsides modeled for Category II types. Category I and III landslide types are "modified" (meaning an increase or decrease in the static susceptibility by a value less than 1) while Category II landslide types are "intensified" (meaning for every antecedent increase of one fuzzy value i.e. "low to medium", the consequent increases by one fuzzy value) (Table 10).

Figure 28 below illustrates this consequence by juxtaposing the two hazard maps. The dry scenario hazard map comprises primarily "low" to "medium" landslide concentrations of 0.1 to 0.316 landslides/km^2 and 0.316 to 1 landslides/km^2, respectively.

The wet scenario shows a marked increase in landslide concentration by about an order of magnitude. This effect is highlighted in the north and southeast portions of the San Francisco South quadrangle. Susceptible areas near the coast and south of the City of San Francisco modeled as "low" to "medium" have generally increased one fuzzy value each to "medium" and "high", respectively.

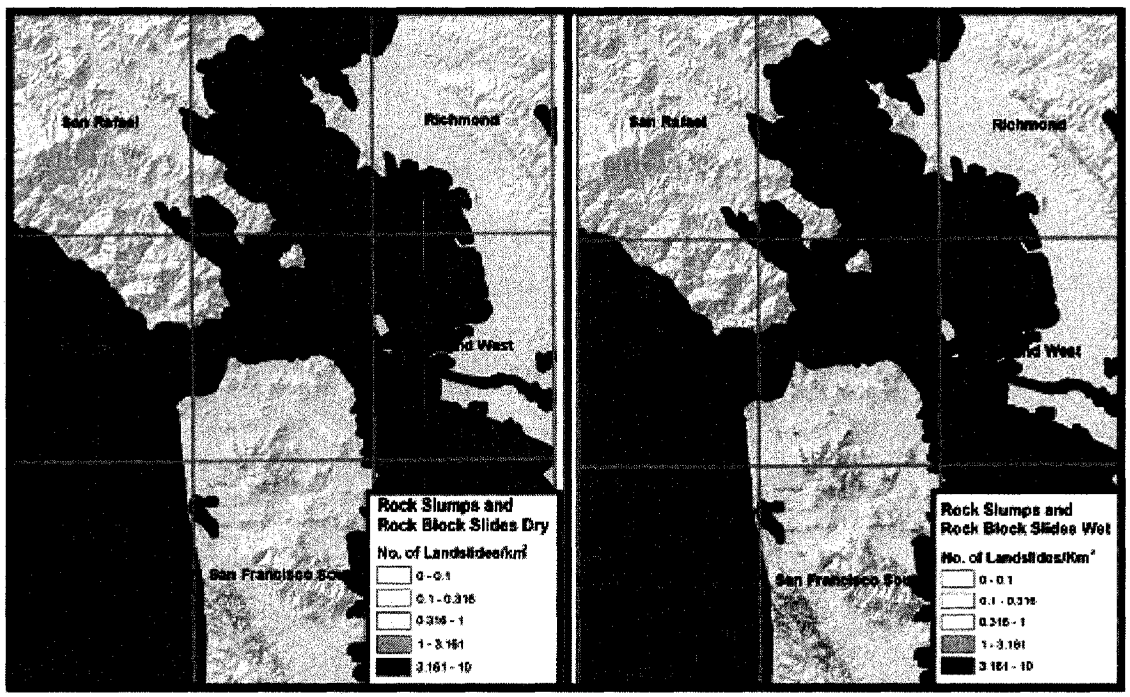


Figure 28. CAMEL results for rock slumps and rock block slides highlighting areas of greatest concentration and/or areas of interest

<u>Soil Block Slides and Soil Slumps</u> Soil slumps and soil block slides occur in much greater abundance than rock slumps and rock block slides by nearly an order of magnitude. This correlates with the framework developed within CAMEL, based on Keefer's 1984 findings. Historically, soil slumps accounted for between 10,000 and 100,000 landslides and rock slumps for about 1,000 to 10,000 landslides based on 40

earthquakes occurring worldwide yet both have the same maximum concentration range (10 landslides/km^2) for the hazard maps. In addition, landslides have been modeled in areas with a minimum slope inclination of about 5 degrees, corresponding with the *pSlopeAngle* established in the CAMEL matrix.

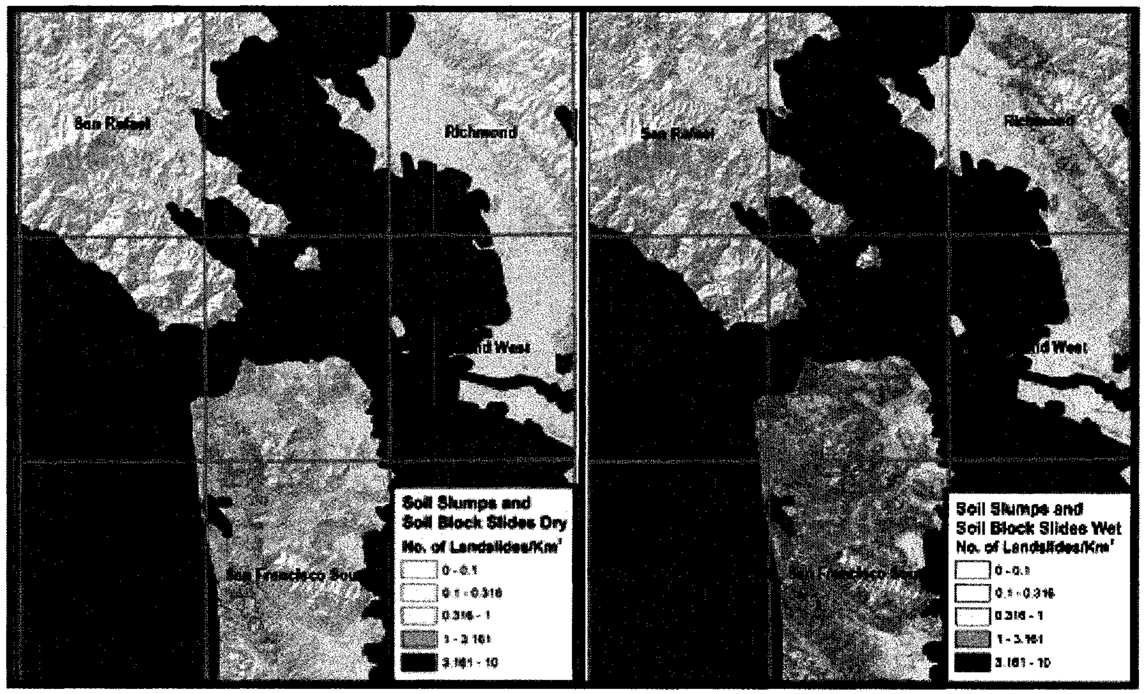


Figure 29. CAMEL results for soil slumps and soil block slides highlighting areas of greatest concentration and/or areas of interest

Figure 29 juxtaposes the wet versus dry scenario results for soil slumps and soil block slides. Much of the areas modeled as "medium" concentration did typically increase one fuzzy value to "high". In contrast, although an increase in the moisture percentage should result in one fuzzy level increase, the majority of the areas initially modeled as "high" did not increase to "very high". An increase to "very high" only occurred in localized areas.

Category III

<u>Rapid Soil Flows</u> Rapid soil flows are the only type of landslide modeled by CAMEL from Category III and have a maximum possible concentration value of 10 landslides/km^2. Soil rapid flows are expected to only occur under partially saturated and saturated conditions. The rules within CAMEL are established to reflect this assumption; therefore, rapid soil flows did not produce any results when CAMEL was run with 12.5% moisture, only the 62.5%.

Figure 30 below presents the results for rapid soil flows modeled by CAMEL. Landslides have been modeled in areas with a minimum slope inclination as low as 2.3 degrees, corresponding with the *pSlopeAngle* established in the CAMEL matrix. Most of the concentrations of rapid soil flows are between "medium" and "high" fuzzy values. This landslide type is particularly concentrated in areas of lower topographic relief. For example, "very low" to "low" landslide concentrations are observed near the higher elevations and crests of the Coast Ranges and Santa Cruz Mountains, increasing in value to "medium" and "high" in the canyons, valleys, stream channels, and outer boundaries of the slopes surrounding the mountains. Within the San Francisco South quadrangle, a linear band of "high" concentration has been identified as the Cotati Formation which, according to Bonilla (1998) consists of friable, well-sorted fine to medium sand containing a few beds of sandy silt, clay, and gravel in northwest and central portions of the map and mostly sandy clay and silty sand in southeast portion.

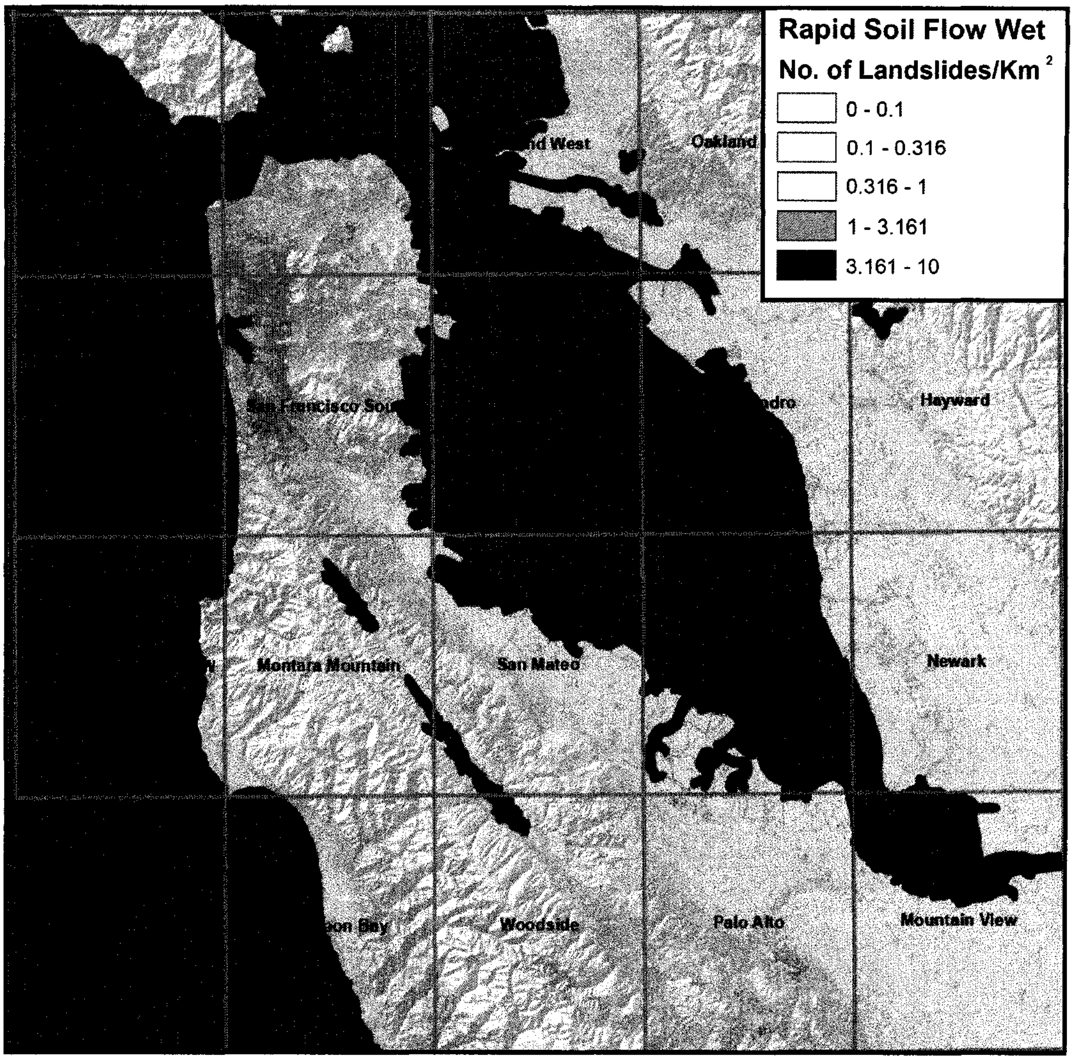


Figure 30. CAMEL results for rapid soil flows highlighting areas of greatest concentration and/or areas of interest

Empirical Evaluation

An empirical analysis was conducted on the CAMEL maps created for the 1906 earthquake. Though reliable information regarding slope movement in the Bay Area during the 1906 event is sparse, mapping and compilation of first-hand accounts conducted shortly after the earthquake by Lawson (1908) as well as other researchers provides possible locations of ground failures. Lawson's and other researchers' information were summarized in *Historic Ground Failures in Northern California Associated with Earthquakes* (Youd and Hoose, 1978).

Youd and Hoose (1978) show locations of ground failures throughout the Bay Area following the 1906 earthquake; location accuracies vary and in some cases errors may be in the order of kilometers. These maps have been digitized for this study. The landslide types identified in *Historic Ground Failures in Northern California Associated with Earthquakes* (Youd and Hoose, 1978) consist of hillside landslides (assumed to be rotational slumps, block slides, debris avalanches and rock fallss) and stream bank failures (assumed to be rotational slumps and soil falls). Both types, with their associated station numbers, have been overlain onto the CAMEL hazard maps (Plates 12 through 22).

Regarding the research conducted, Lawson et al. (1908) noted:

1. Slumps were by far the most common manifestation of landslides and a complete assessment would be virtually impossible;
2. Rapid soil flows typically originated in valleys, gullies, and hillsides concentrating along the coast and within the Santa Cruz Mountains, Diablo Range, and Hamilton Range. They were formed on both gentle and steep hillslopes and in both previously dry drainage depressions and convex hillsides;

3. Dry earth and rock slid from precipitous slopes and fell from cliffs. Soil or other debris were observed, but rock was the primary material, becoming shattered as the slides progressed;
4. Soil and rock falls were located chiefly along the coast, though some occurred in steep canyons where the shaking intensity was strong;
5. Along the coast, some immense landslides occurred

Because specific numbers were not consistently used to describe the quantities of landslides, a statistical analysis is infeasible. However, a qualitative analysis of the station locations and the concentration of landsides modeled by CAMEL are presented in Figures 31 through 35 below. The figures used for the empirical evaluation incorporate the identical areas presented during the results section of this study.

Several stations (e.g. 74, 82, and 99) are repeated on the maps. The total of all stations represent 127 hillside and 26 stream bank landslide locations in the area modeled by CAMEL. Within the areas of interest for each landslide hazard map, the red circles and orange squares represent the locations of landslides of undifferentiated types (red circles for hillside and orange squares for sreambank failures). The green markers (circles or squares) are the locations of landslides of identified type, placed on the map of the corresponding type as modeled by CAMEL. For simplicity, no distinction was made between streambank failures as rotational slumps or soil falls and both are marked as such on their respective hazard maps. The empirical analysis utilized the above details and notes associated with the stations in Youd and Hoose (1978) to assess the type of landslide that may have occurred at particular stations. Within the area of interest, 101 stations were located on the maps. Several of these stations represent multiple landslides. These findings are summarized in the table in Appendix C. The table contains the station number, the number of landslides (specific number, few, some, or several), the location (hillside or stream bank), the category of landslide as defined by Keefer (1984), and the original evidence or designation. Regarding landslide quantity, if a specific number was stated in the original source (i.e. 1 or 2) then this was used, but often qualitative designations such as "few", "some", or "several" were given. In a number of instances synonyms were noted in the text of the report; therefore, minor equals few, and words such as abundant, numerous, etc. are equivalent to several. A number of stations did not contain sufficient descriptions to ascertain the type of landslide that may have occurred. These were given "unknown" designations in the table in Appendix C.

Category I

Category I landslides comprise the majority of identified landslides generated during the 1906 earthquake, referred to as "earth avalanches" by Lawson (1908) and Youd and Hoose (1978). Earth avalanches were defined herein as including both rock falls and soil falls. If one of these types was further discernible from the literature then that particular station or location was separated and placed on the appropriate hazard map.

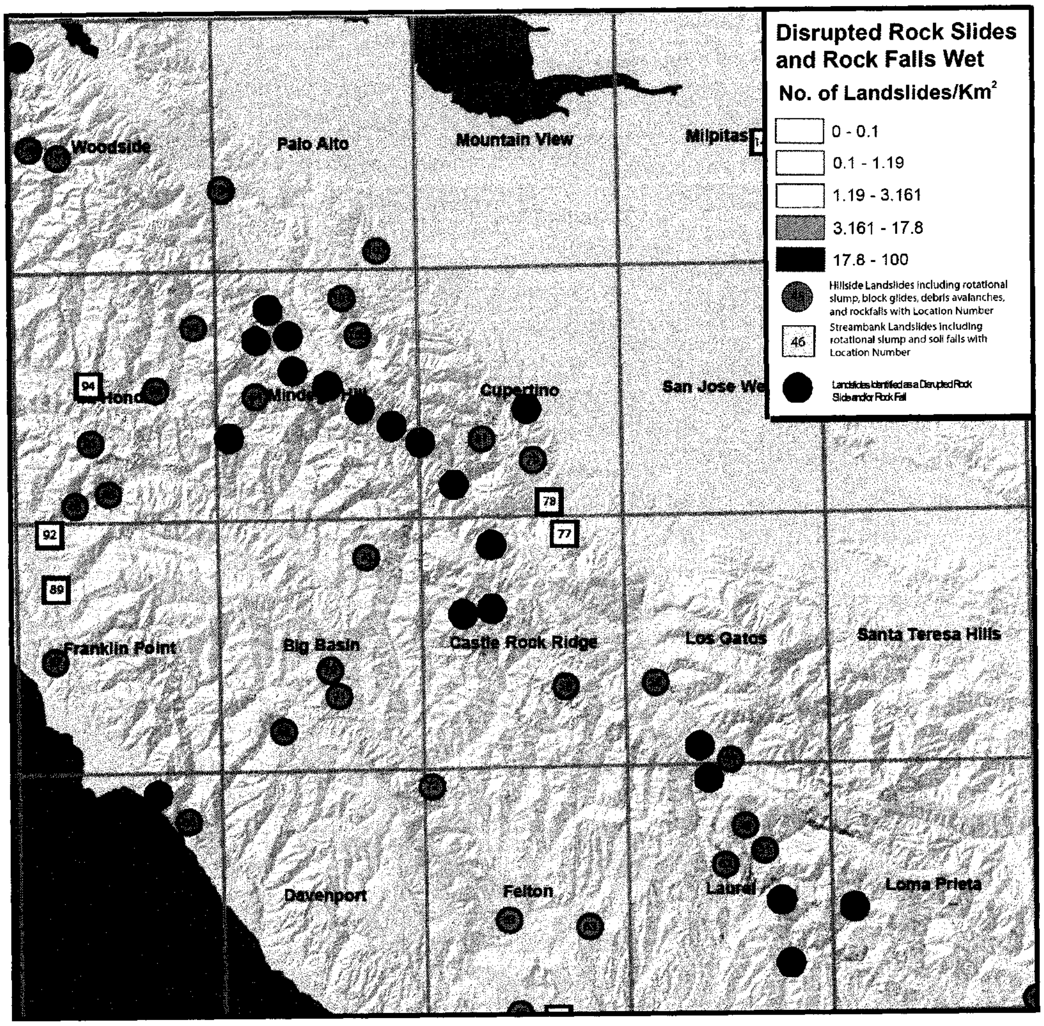


Figure 31. Disrupted rock slides and rock falls with locations of actual landslides mapped by Lawson (1908)

The landslides typically occurred along or near the trace of the San Andreas Fault through the Santa Cruz Mountains and within areas of relatively high elevation and relief. This was particularly observed for disrupted rock slides and rock falls. In general, the identified rock falls appear to have occurred in areas modeled by CAMEL representing "medium" to "high" hazards with very few to none being mapped in areas of "low" to "very low" hazard (Fig. 31).

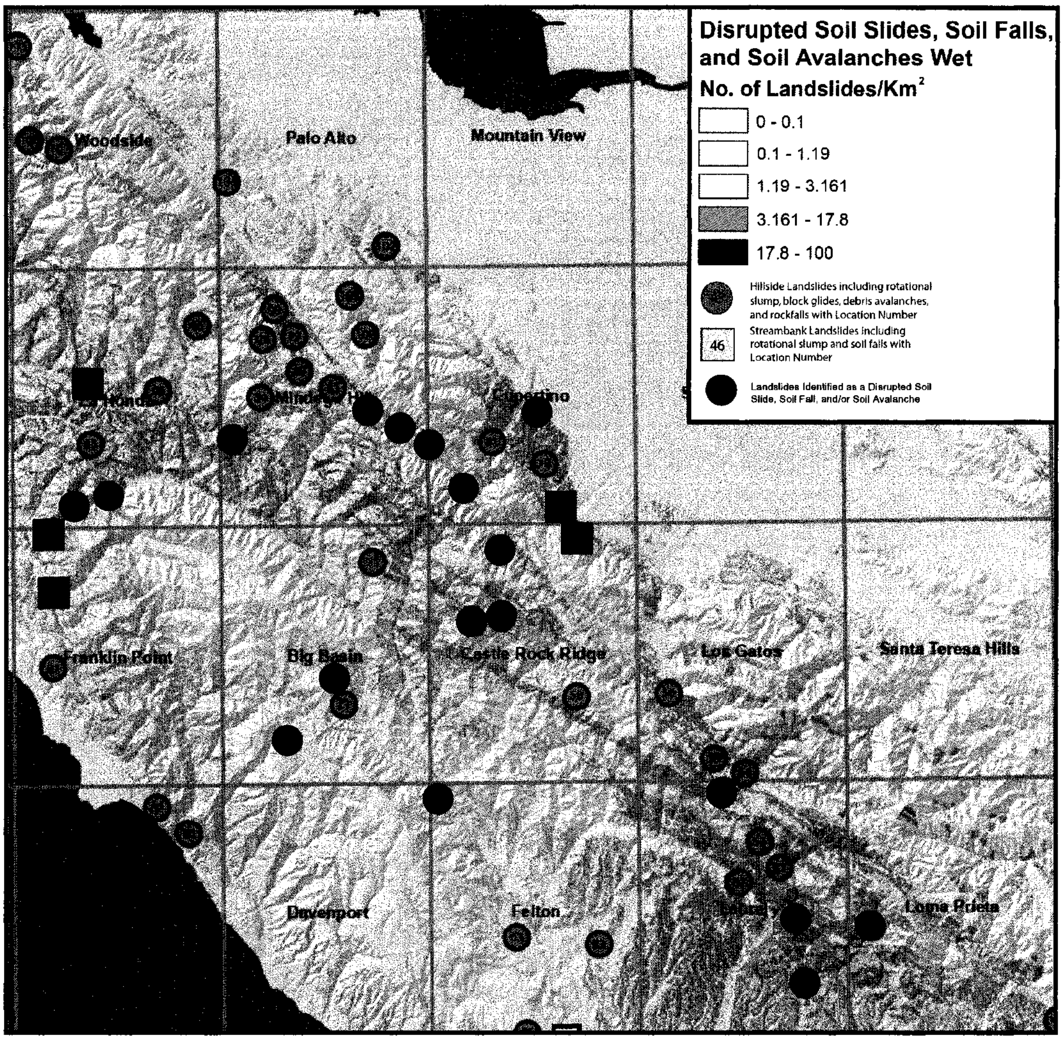


Figure 32. Disrupted soil slides, soil falls, and soil avalanches with locations of actual landslides mapped by Lawson (1908)

The soil falls follow a similar pattern of correspondence between the concentrations modeled by CAMEL and the mapped landslide occurrence and additionally include streambank failures along with the hillside landslides. The streambank failures, as with the hillside failures, occurred in terrain and areas of the map modeled by CAMEL as "medium" to "high" concentrations (Fig. 32).

Category II

As in the results section of this thesis, the area highlighted during the empirical evaluation for rock slumps/soil block slides and soil slumps/soil block slides is in and surrounding the City of San Francisco. A single failure attributable to rock slumping and block sliding was mapped in the area of interest (Fig. 33). Of the different types of landslides assessed, this type is possibly the most underrepresented, both in recognition during the literature review and perhaps in the mapping itself conducted by Lawson (1908). A total of five stations were identified as possible locations of rock slumps and block slides throughout the San Francisco Bay Area. Though this type of landslide is the second lowest in terms of concentration modeled by CAMEL, a larger total number of actual landslides mapped would be expected.

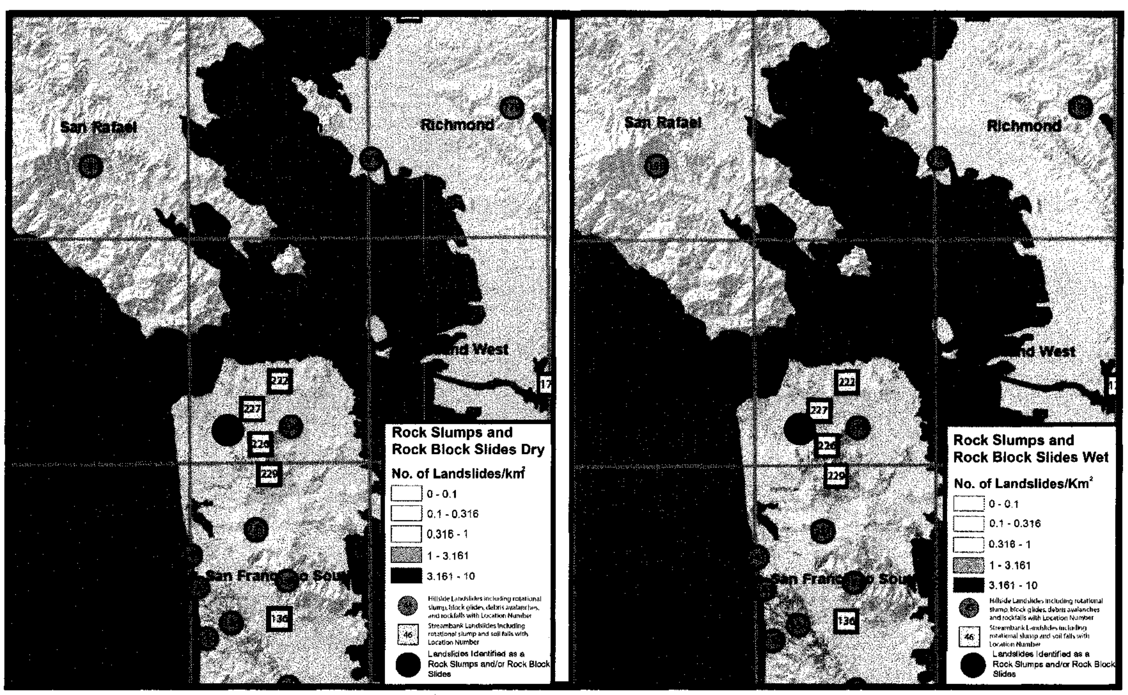


Figure 33. Rock slumps and rock block slides with locations of actual landslides mapped by Lawson (1908)

Actual landslide occurrences throughout the San Francisco Bay Area are assumed to be under-represented in the mapping by Lawson (1908) and cited in Youd and Hoose (1978). Lawson (1908) specifically recognized this fact in the case of earth slumps, "By far the most common manifestation of landslide phenomena was that here referred to as earth-slump. It would be wearisome to attempt to mention all the various earth-slumps stimulated by the earthquake, even if information were sufficiently detailed to make this possible." This quotation indicates that although the majority of identified landslides within the area of interest consisted of Category I landslides, a large number of Category II landslides may have gone unmapped.

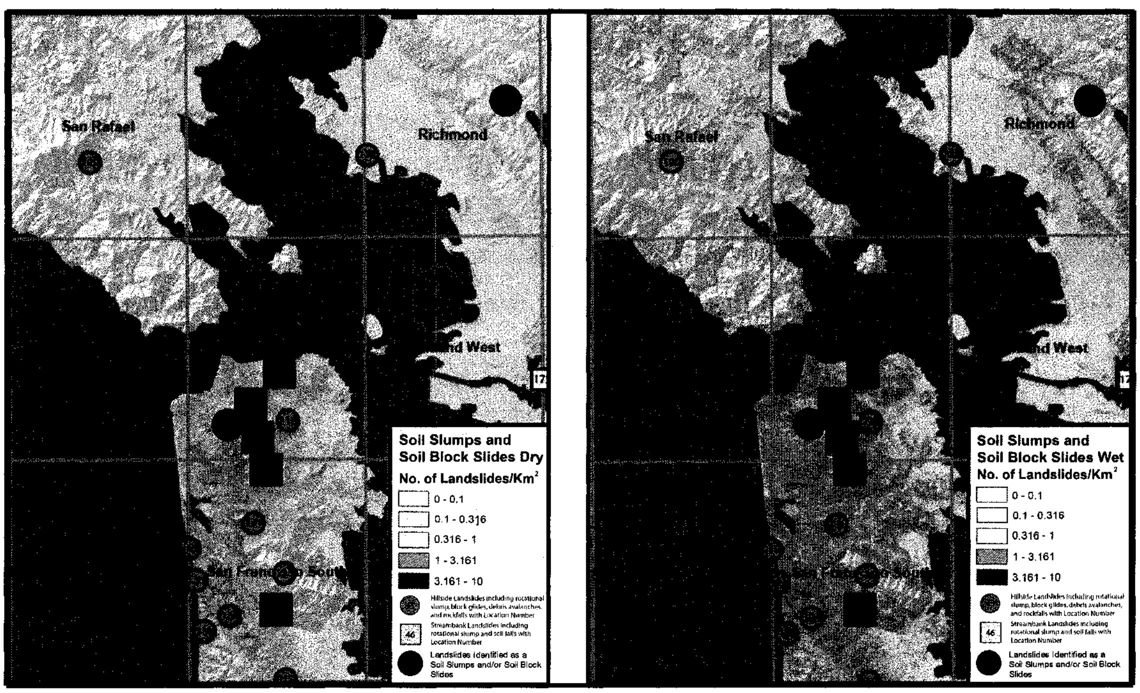


Figure 34. Soil slumps and soil block slides with locations of actual landslides mapped by Lawson (1908)

Stations 227, 228, and 229 are overlain on areas modeled as “very high” concentrations by CAMEL. These landslides identified as soil slumps and soil block slides are, for the most part, streambank failures in this area (Fig. 34).

Category III

The 1906 earthquake occurred late in the rainy season in the San Francisco Bay Area in a year of above average rainfall; therefore, rapid soil flows would be expected to occur. The interpretation of this type of landslide from the notes in Youd and Hoose (1978) focused on terms such as earthslips and landslips normally in relation to springs or flowing water from the source of the landslide.

Rapid soil flows were observed in several locations in the Bay Area, and within the portion of the hazard map selected for the results and empirical evaluation (Fig. 35). For the most part these landslides were recognized from the literature as being mapped in flatter topography along the edges of the Coast Range and Santa Cruz Mountains in areas modeled as “medium” to “high” concentrations.

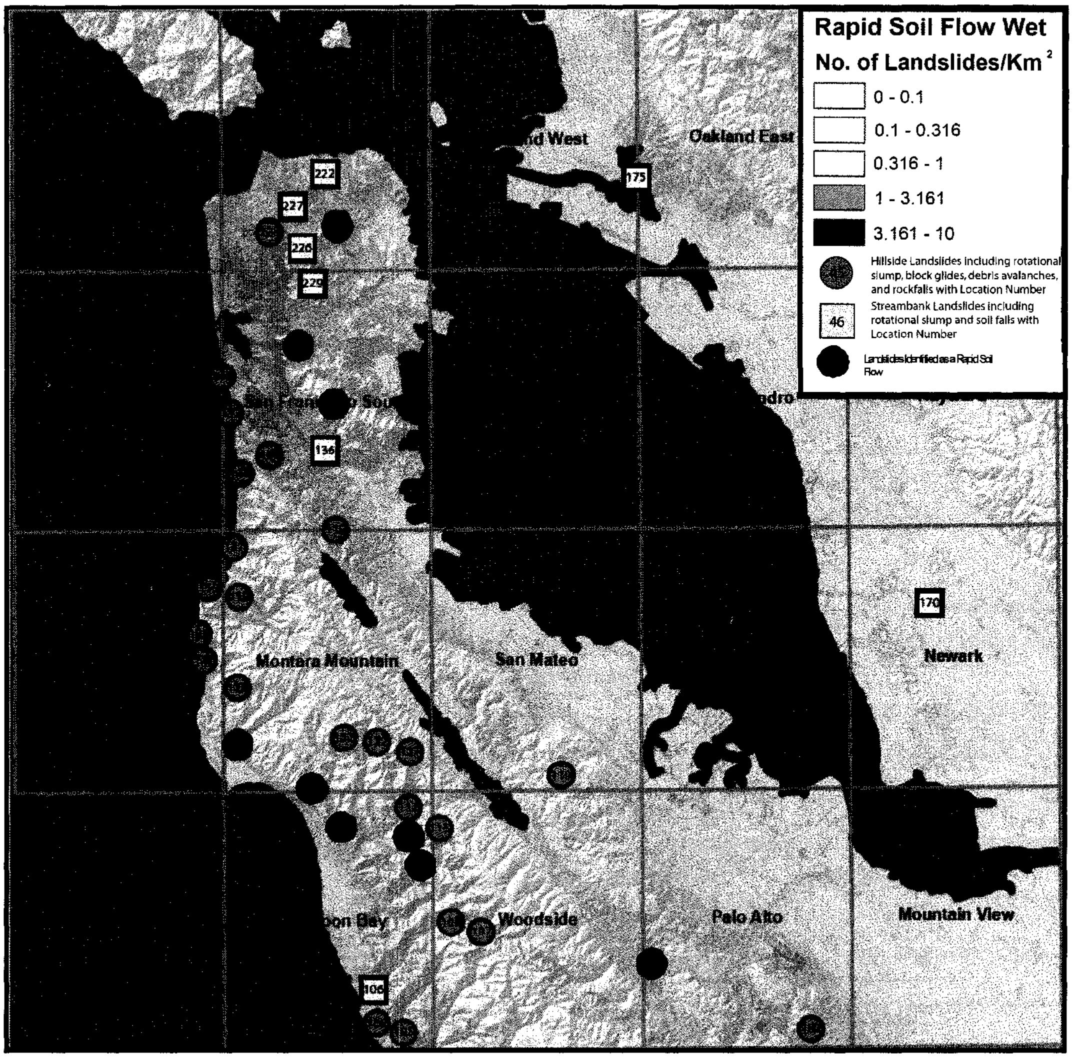


Figure 35. Rapid soil flows with locations of actual landslides mapped by Lawson (1908)

In general, the landslides observed post-1906 earthquake qualitatively correlate with locations modeled by CAMEL. The majority of actual landslides occurred near the trace of the San Andreas Fault in the Santa Cruz Mountains, with pronounced dissipation in the concentration of stations to the north and east. Where stations were associated with a specific category or type of landslide, landsliding typically occurred in areas modeled as “medium” to “very high” by CAMEL. In addition, when a station was unidentified for certain type, the landslides still usually occurred in areas modeled as “medium” to “very high” on maps such as soil slumps/soil block slides and soil falls/disrupted soil slides/soil avalanches that present typically high levels of activity throughout the Bay Area.

Perhaps even more significant than locating mapped landslides in areas of “medium” to “very high” concentrations is the lack of occurrence of actual landsliding in areas modeled by CAMEL with “very low” and “low” concentrations for all three categories. A crucial facet of any useful hazard model is the ability to separate these two types of areas. CAMEL appears to be capable of this feat. For example, no maps contain significant concentrations (greater than “low”) in the Davennport quadrangle and the mapping by Lawson (1908) reflects this as well. The comparison of mapped landslide location with the hazard areas determined by CAMEL indicates that CAMEL has modeled well the possible locations of earthquake-induced landslides.

Ameliorations

The empirical comparison described in this thesis could be improved because the descriptions of landslides in Youd and Hoose (1978) are unreliable and incomplete, not describing the characteristics of movement, only the occurrence. Running CAMEL for the 1989 Loma Prieta earthquake in the San Francisco Bay Area and other better documented earthquakes (including the Northridge, CA and Chi-Chi, Taiwan earthquakes) would enable a stronger statistical comparison between the model and reality, as in Miles (2004) dissertation.

CAMEL is a progression in the development of earthquake-induced landslide hazard characterization, although some advancement could improve the model. A better characterization of ground water conditions and soil depth would allow for a better evaluation of the Category II landslides caused by the earthquakes. Currently, ground water is modeled either as unsaturated (12.5%) or saturated (62.5%) when running CAMEL. If this could be refined, a stronger control over the impact of water on landslides would be contained within the model. The soil depth used for this study was 4 m to assure no landslides would be excluded. Because of this, soil-based landslides were exaggerated. Perhaps the largest improvement would be to have a more accurate determination of soil depth. The Natural Resource Conservation Service (NRCS) provides GIS layers for soil types along with depth descriptions on their website. If these could be combined and added into CAMEL, control over soil depth would be greatly improved.

CAMEL may benefit from being made more capable of treating each landside type individually, so that, for example, soil avalanches are not indicated by the same slope angle value as disrupted soil slides. Also, soil lateral spread failures currently are not modeled by CAMEL but potentially could be included.

One of the problems that arose during the process of operating CAMEL within the GIS was the inability of the model to effectively communicate errors. A more adaptive graphical user interface (GUI) would permit a larger cross-section of the population to implement CAMEL.

CONCLUSIONS

The purpose of this thesis was to create earthquake-induced landslide hazard maps using the Comprehensive Areal Model for Earthquake-Induced Landslides for the 100th Anniversary Earthquake Conference Commemorating the 1906 San Francisco Earthquakee and to assess the capabilities of the model for regional regulation purposes. CAMEL was originally created to be a more accurate and complete method of generating hazard maps that could be implemented by local communities for development and safety practices.

The maps generated for this study demonstrates the inherent dangers associated with areas like the San Francisco Bay Area. The model offers the ability to quantify these potential threats to both life and property with the likelihood of specific landslide types. For example, the high occurrence of "low-angle" ($\geq$2.3, 5 to 10) landslides, such as rapid soil flows and soil slumps and soil block slides, respectively, illustrates the susceptibility of large metropolises (i.e. the City of San Francisco) to slope instabilities even though they may be in relatively low lying areas.

The empirical evaluation using the 1906 landslide locations, though generalized for type, and the concentrations mapped by CAMEL illustrates that landslides in 1906 were concentrated along the trace of the San Andreas Fault, in weak lithology, and along the coast. Detailed conclusions are difficult to make because detailed information about landslide types is not available for the 1906 San Francisco Earthquake inventory, as is also the case with many other data sets.

A ShakeMap portraying the ground motion intensities derived from the 1906 San Francisco Earthquake was utilized in this study. Other readily available shake intensity maps could also be incorporated into the model for variable earthquake scenarios in the Bay Area, for example, along the Hayward-Rogers Creek Fault(s) or the Calaveras Fault. If implemented, CAMEL could be a significant advanceme in disaster-risk reduction with respect to the socio-economic impact of the different types of earthquake-induced landslides.

REFERENCES

Berkan, R. and Trubatch, S., 1997, Fuzzy Systems Design Principles: Building Fuzzy IF-THEN Rule Bases. New York: IEEE Press.

Bommer, J. and Rodríguez, C., 2002, Earthquake-induced landslides in Central America. Engineering Geology, 63, p. 189–220.

Boatwright, J. and Bundock, J., 2005, MMI ShakeMap of California for the 1906 San Francisco earthquake inferred from Lawson (1908), http://quake.wr.usgs.gov/research/strongmotion/effects/1906/

Bromhead, E.N., 1986, The stability of slopes, Blackie & Sons, Surrey, United Kingdom, 373 p.

Bonilla, M.G., 1998, Preliminary geologic map of the San Francisco South 7.5' quadrangle and part of the Hunters Point 7.5' quadrangle, San Francisco Bay area, California: a digital database: U.S. Geological Survey, Open-File Report OF-98-354, scale 1:24 000.

Brown, R.D., 1990, Quaternary Deformation *in* The San Andreas Fault System, California, Wallace, R. E. ed.: United States Geological Survey Professional Paper 1515, p. 83–85.

California Building Code, 2001, California Building Standards Commission.

California Department of Conservation, California Geological Survey, 2002, Generalized Geologic Map of California, Note 17.

California Department of Conservation Division of Mines and Geology, 1986, Guidelines for Geologic/Seismic Reports, CDMG Note 42.

California Department of Conservation Division of Mines and Geology, 1997, Guidelines for Evaluating and Mitigating Seismic Hazards in California, Special Publication 117, p. 31–32.

Cao, T., Bryant, W.A., Rowshandel, B., Branum, D., and Wills, C.J., 2003, The Revised 2002 California Probabilistic Seismic Hazards Maps, California Geological Survey, June 2003, http://www.consrv.ca.gov/CGS/rghm/psha/fault_parameters/pdf/2002

Chin, J.L., Morrow, J.R., Ross, C.R., and Clifton, H.E., 1993, Geologic Maps of Upper Cenozoic Deposits in Central California, U.S. Geological Survey, Miscellaneous Investigation Series Map I-1943, scale 1:250 000.

Chowdhury, R.N., 1978, Slope analysis: Elsevier Scientific Publishing Company, Amsterdam, 423 p.

Cottecchia, V., 1987, Earthquake-prone environments, *in* Anderson, M.G. and Richards, K.S., ed., Slope stability, geotechnical engineering and geomorphology: John Wiley & Sons, New York, p. 287–330.

Cruden, D. and Varnes, D., 1996, Landslide Types and Processes, *in* A. Turner and R. Schuster, ed., Landslides: Investigation and Mitigation: Transportation Research Board, National Research Council, Special Report 247, p. 36–75.

Duncan, J.M., 1996, Chapter 13, soil slope stability analysis, *in* Turner, A. and Schuster, R.L., ed., Landslides: Investigation and Mitigation: Transportation Research Board, National Research Council, Special Report 247, p. 337–371.

Easterbrook, D.J., 1999, Surface Processes and Landforms: Upper Saddle River, Prentice-Hall, p. 80–81

Ellen, D.S. and Wentworth, C.M., 1995, Hillside Materials and Slopes of the San Francisco Bay Region, California: U.S. Geological Survey Professional Paper 1357.

Ellsworth, W.L., 1990, Earthquake history, 1769-1989, chap. 6 of Wallace, R.E., ed., The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515, p. 152–187.

Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S., 2002, Documentation for the 2002 Update of the National Seismic Hazard Maps, USGS Open File Report 02-420, Denver, CO, http://pubs.usgs.gov/of/2002 /ofr-02-420/OFR-02-420.pdf.

Frankel, A.D., Mueller, C.S., Barnhard, T., Perkins, D.M., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M., 1996, National Seismic Hazard Maps, June 1996 Documentation, USGS Open File Report 96-532, Denver, CO, http://geohazards.c r.usgs.gov/eq

Graymer, R.W., 2000, Geologic map and map database of the Oakland metropolitan area, Alameda, Contra Costa, and San Francisco Counties, California: U.S. Geological Survey, Miscellaneous Field Studies Map MF 2342, scale 1:50 000.

Graymer, R.W., Moring, B.C., Saucedo, G.J., Wentworth, C.M., Brabb, E.E., and Knudsen, K.L., 2006, Geologic map of the San Francisco Bay region: U.S. Geological Survey, Scientific Investigations Map SIM-2918, scale 1:275 000, http://pubs.usgs.gov/sim/2006/2918/

Hancox, G.T., Perrin, N.D., and Dellow, G.D., 2002, Recent Studies of Historical Earthquake-Induced Landsliding, Ground Damage, and MM Intensity in New Zealand: Bulletin of the New Zealand Society for Earthquake Engineering, vol. 35, No. 2, p. 59–94.

Hansen, A. and Franks, C., 1991, Characterisation and mapping of earthquake triggered landslides for seismic zonation, *in* Proceedings of the Fourth International Conference on Seismic Zonation, Palo Alto, CA. p. 149–195.

Hart, E.W. and Bryant, W.A., 1997, Fault-Rupture Hazard Zones in California: California Division of Mines and Geology, Special Publication 42, 1997 revised edition.

Houston, S.L. Houston, W.N., and Padilla, J.M., 1987, Microcomputer-aided evaluation of earthquake-induced permanent slope displacements: Microcomputers in Civil Engineering, v. 2, p. 207–222.

Hsu, K., 1975, On sturzstroms—catastrophic debris streams generated by rockfalls: Geologic Society of America Bulletin, vol. 86, p. 129–140.

Hunt, R.E., 1948, Geotechnical investigation manual: McGraw-Hill Book Co., New York, 729 p.

Hynes, M.E. and Franklin, A.G., 1984, Rationalizing the seismic coefficient method: U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Miscellaneous Paper GL-84-13, July 1984.

International Conference of Building Officials, 1998, Maps of Known Active Fault Near-Source Zones in California and Adjacent Portion of Nevada – To be used with the 1997 Uniform Building Code, prepared by the California Department of Conservation, Division of Mines and Geology in cooperation with Structural Engineers Association of California – Seismology Committee, February.

Janbu, N., 1973, Slope stability computations, *in* Hirschfield, R.C. and Poulos, S.J., ed., Embankment-Dam Engineering, John Wiley & Sons, New York, p. 47–86.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas: California Division of Mines and Geology, Geologic Data Map GDM No. 6, scale 1:750 000.

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council: Transportation Research Record 1411, 17 p.

Kanamori, H., 1977, The Energy Release in Great Earthquakes: Journal of Geophysical Research, Vol. 82, p. 2981–2987.

Keefer, David K., 1984, Landslides Caused by Earthquakes: Geological Society of America Bulletin. Vol. 95, p. 406–421.

Keefer, David K., 1993, The Susceptibility of Rock Slopes to Earthquake-Induced Failures: Bulletin of Association of Engineering Geologists, Technical Notes p. 353–361.

Keefer, David K., 1998, The Loma Prieta, California earthquake of October 17, 1989 – Landslides: U.S. Geological Survey Professional Paper 1551-C, 185 p. + 5 plates.

Keefer, David K., 1999, Earthquake-Induced Landslides and Their Effects on Alluvial Fans: Journal of Sedimentary Research. Vol. 69, No. 1, p. 84–104.

Keefer, David K., 2000, Statistical Analysis of an Earthquake-Induced Landslide Distribution – the 1989 Loma Prieta, California Event: Engineering Geology. Vol. 58, p. 231–249.

Keefer, David K., 2002, Investigating Landslides Caused by Earthquakes – a Historical Review: Surveys in Geophysics. Vol. 23, p. 473–510.

Keefer, D.K., Miles, S., Swank, M., and Blair, J.L., 2006, A CAMEL-based assessment of earthquake-induced landslide hazards in the San Francisco Bay region, California (Abstract): Seismological Society of America Centennial Meeting, San Francisco, April 18-22, 2006, SSA-0125.

Lawson, A.C., 1908, The California earthquake of April 18, 1906: report of the State Earthquake Investigation Commission, Carnegie Institution of Washington Publication 87, two volumes.

Liao, C., Lee C., and Liao, H., 2002, Statistical Analysis of Factors Affecting Landslides Triggered by the 1999 Chi-Chi Earthquake, Taiwan, Asian Conference on Remote Sensing ACRS 2000, http://www.gisdevelopment.net/aars/acrs/2000/ts8/hami 0007.htm

Makdisi, F.I. and Seed, H.B., 1978, Simplified procedure for estimating dam and embankment earthquake-induced deformations: Proceedings of the American Society of Civil Engineers, Journal of Geotechnical Engineering, vol. 104, number GT7, p. 849–847.

McCrink, T. and Real, C., 1996, Evaluation of the Newmark Method for Mapping Earthquake-Induced Hazards in the Laurel 7.5' Quadrangle, Santa Cruz County, California: Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334.

McCrink, T., 2001, Regional Earthquake-Induced Landslide Mapping Using Newmark Displacement Criteria, Santa Cruz County California, *in* H. Ferriz and R. Anderson, ed., Engineering Geology Practice in Northern California, p. 77–93.

McLaughlin, R.J., Clark, J.C., Brabb, E.E., Helley, E.J., and Wentworth, C.M., 2004, Geologic map of the Loma Prieta region, California: U.S. Geological Survey, Professional Paper 1550-E, Plate 1, scale 1:50 000.

Miles, S.B., 2004, Participatory Assessment of a Comprehensive Areal Model of Earthquake-Induced Landslides, PhD dissertation: University of Washington.

Miles, S.B., and Keefer, D.K., 2007, Comprehensive Areal Model of Earthquake-Induced Landslides: technical specification and user guide: U.S. Geological Survey Open-File Report 2007-1072, http://pubs.usgs.gov/of/2007/1072/

Morgenstern, N.R. and Sangrey, D.A., 1978, Chapter 7, Methods of stability analysis, *in* Schuster, R.L. and Krizek, R.J., ed., Landslides–analysis and control: National Academy of Sciences, Washington D.C., p 155–172.

Nash, D.F.T., 1987, A comparative review of limit equilibrium methods of the stability analysis, *in* Anderson, M.G. and Richards, K.S., ed.,, Slope stability–geotechnical engineering and geomorphology, John Wiley & Sons, New York, p. 11–76.

Newmark, N.M., 1965, Effects of earthquakes in dams and embankments: Geotechnique, v. 15, n. 2, p. 139–160.

Norrish, N.I. and Wylie, D.C., 1996, Rock Slope Stability Analysis, *in* A. Turner and R. Schuster, ed., Landslides: Investigation and Mitigation: Transportation Research Board, National Research Council, Special Report 247, p. 391–424.

Parise, M. and Jibson, R., 2000, A seismic landslide susceptibility rating of geologic units based on analysis of characteristics of landslides triggered by the 17 January, 1994 Northridge, California earthquake: Engineering Geology, vol. 58, p. 251–270.

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: Division of Mines and Geology Open File Report 96-08, http://www.consrv.ca.gov/dmg/shezp /fltindex.html

Rodriguez, C., Bommer, J. and Chandler, R., 1999, Earthquake-induced landslides: 1980-1997: Soil Dynamics and Earthquake Engineering, vol. 18, p. 325–346.

Schlocker, J., 1971, Generalized geologic map of the San Francisco Bay region, California: U.S. Geological Survey, Open-File Report OF-71-246, scale 1:500 000.

Sidle, R.C., Pearce, A.J., and O'Loughlin, C.L., 1985, Hillslope Stability and Land Use, Water Resources Monograph 11th Edition, American Geophysical Union, 140 p.

Varnes, D.J., 1978, Slope movement types and processes, *in* R. Schuster and R. Krizek ed., Landslides – Analysis and Control. National Academy Science Transportation Research Board Special Report, 176, p. 11–33.

Wagner, D.L., Bortugno, E.J., and McJunkin, R.D., 1991, Geologic map of the San Francisco San Jose quadrangle, California, 1:250 000: California Division of Mines and Geology, Regional Geologic Map Series 5A, scale 1:250,000.

Wakabayashi, J., and Smith, D.L., 1994, Evaluation of recurrence intervals, characteristic earthquakes and slip rates associated with thrusting along the Coast Range-Central Valley geomorphic boundary, California: Bulletin of the Seismological Society of America, vol. 84, p.1960–1970.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863–877.

Working Group on California Earthquake Probabilities, 2003, Earthquake Probabilities in the San Francisco Bay Region: 2002-2031 U.S. Geological Survey, Open File Report 03-214.

Wu, T., Tang, W. and Einstein, H., 1996. Landslide Hazard and Risk Assessment, *in* A. Turner and R. Schuster, ed., Landslides: Investigation and Mitigation: Transportation Research Board, National Research Council, Special Report 247, p. 12–35.

Youd, T.L. and Hoose, S.N., 1978, Historic Ground Failures in Northern California Triggered by Earthquakes: United States Geological Survey Professional Paper 993.

Zadeh, L. (1965) Fuzzy sets: Information and Control, vol. 8, p. 338–353.

APPENDIX A: COMPREHENSIVE AREAL MODEL OF EARTHQUAKE-INDUCED LANDSLIDES: TECHNICAL SPECIFICATION AND USER GUIDE

Located on CD

APPENDIX B: MATERIAL CLASS VALUES FOR GEOLOGIC UNITS IN THE SAN FRANCISCO BAY AREA

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1	NESF	Soil	ac	artificial channel	5.00		
2	NESF	Soil	ads	artificial dredge spoils	5.00		
3	NESF	Soil	af	artificial fill	5.00		
4	NESF	Soil	afbm	artificial fill over Bay mud	5.00		
5	NESF	Soil	alf	artificial levee fill	5.00		
6	ESWN	Soil	af	artificial fill	5.00		
7	ESWN	Soil	afbm	artificial fill over Bay mud	5.00		
8	ESWN	Soil	alf	artificial levee fill	5.00		
9	WSO	Soil	af	artificial fill	5.00		
10	MA	Soil	Qaf	Artificial fill	5.00		
11	MA	Soil	Qmf	Artificial fill over marine and marsh deposits	5.00	Quaternary	Quaternary
12	AL_CC	Soil	ac	artificial channel	5.00		
13	AL_CC	Soil	af	artificial fill	5.00		
14	AL_CC	Soil	alf	artificial levee fill	5.00		
15	AL_CC	Soil	GP	gravel pit	5.00		
16	AL_CC	Soil	Qhasc	artificial stream channels	5.00		
17	SFS	Soil	Qaf	artificial fill	5.00		
18	SFS	Soil	Qaf/tf	artificial fill over tidal flat	5.00		
19	SFS	Soil	Qafs	artificial fill, shellmound	5.00		
20	SM	Soil	af	artificial fill	5.00		
21	SM	Soil	alf	artificial levee fill	5.00		
22	SM	Soil	Qhasc	artificial stream channel	5.00		
23	PA100	Soil	af	artificial fill	5.00		
24	PA100	Soil	alf	artificial levee fill	5.00		
25	PA100	Soil	Qhasc	artificial stream channel	5.00		
26	SJ100	Rock	?		5.00		
26	SJ100	Rock	?		5.00		
26	SJ100	Rock	?		5.00		
27	SJ100	Soil	af	artificial fill	5.00		
28	SJ100	Soil	GP	gravel pit	5.00		
29	SJ100	Rock	PP	Percolation pond	5.00	Modern	Modern
29	SJ100	Rock	PP	Percolation pond	5.00	Modern	Modern
29	SJ100	Rock	PP	Percolation pond	5.00	Modern	Modern
30	SSC	Soil	af	artificial fill	5.00		
31	SSC	Soil	alf	artificial levee fill	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
32	SSC	Soil	Qhasc	artificial stream channel	5.00		
33	OAK	Soil	af	artificial fill	5.00		
34	OAK	Soil	alf	artificial levee fill	5.00		
35	OAK	Soil	Qhasc	Artificial stream channels	5.00		
36	LOMA	Soil	af	Artificial fill	5.00		
37	LOMA	Soil	gp	gravel pit	5.00		
38	LOMA	Soil	md	mine dump	5.00		
39	LOMA	Rock	pp	Percolation pond	5.00	Modern	Modern
40	MO100	Soil	af	artificial fill	5.00		
41	TR_GEO4	Soil	ac	artificial channel	5.00		
42	TR_GEO4	Soil	af	artificial fill	5.00		
43	PE_GEO10	Soil	af	artificial fill	5.00		
44	NOVA_GEO9	Soil	af	artificial fill	5.00		
45	NOVA_GEO9	Soil	afbm	artificial fill over Bay mud	5.00		
46	NOVA_GEO9	Soil	alf	artificial levee fill	5.00		
47	CORD_GEO8	Soil	af	artificial fill	5.00		
48	FAIR_GEO3	Soil	af	artificial fill	5.00		
49	NESF	Rock	Tlj	Las Juntas Shale	2.75		
50	NESF	Rock	Tljl	Las Juntas Shale, lower member	2.75		
51	NESF	Rock	Tlju	Las Juntas Shale, upper member	2.75		
52	NESF	Rock	Tm	Meganos Formation	3.00	Paleocene	Paleocene
53	ESWN	Rock	Td	sandstone, Eocene and(or) Paleocene, Napa	2.50		
54	ESWN	Rock	Ts?	sandstone, Eocene and(or) Paleocene, Lake Berryessa	2.50		
55	WSO	Rock	Tg	German Rancho Formation	2.50		
56	AL_CC	Rock	Tlj	Las Juntas Shale	2.75		
57	AL_CC	Rock	Tlj?	Las Juntas Shale?	2.75		
58	AL_CC	Rock	Tljl	Las Juntas Shale, lower member, sandstone	2.75		
59	AL_CC	Rock	Tlju	Las Juntas Shale, upper member	2.75		
60	AL_CC	Rock	Tma	Meganos Formation, lower member	3.00		
61	AL_CC	Rock	Tmc	Meganos Formation, shale member	3.25		
62	AL_CC	Rock	Tmcs	Meganos Formation, shale member, sandstone interbeds	3.00		
63	AL_CC	Rock	Tmd	Meganos Formation, sandstone member	3.00		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
64	AL_CC	Rock	Tme	Meganos Formation, upper member	3.00		
65	AL_CC	Rock	Tsh	shale, Eocene and(or) Paleocene, Oakland Hills	2.50	Eocene	Paleocene
66	SJ100	Rock	Tgs	glauconitic ss, red mds, east of Anderson, Coyote Res	2.25	Eocene	Paleocene
66	SJ100	Rock	Tgs	glauconitic ss, red mds, east of Anderson, Coyote Res	2.25	Eocene	Paleocene
66	SJ100	Rock	Tgs	glauconitic ss, red mds, east of Anderson, Coyote Res	2.25	Eocene	Paleocene
67	SJ100	Rock	Tgs?	glauconitic ss, red mds?	2.25		
67	SJ100	Rock	Tgs?	glauconitic ss, red mds?	2.25		
67	SJ100	Rock	Tgs?	glauconitic ss, red mds?	2.25		
68	SSC	Rock	Tgs	glauconitic sandstone, Coyote Reservoir	2.25	Eocene	Paleocene
68	SSC	Rock	Tgs	glauconitic sandstone, Coyote Reservoir	2.25	Eocene	Paleocene
68	SSC	Rock	Tgs	glauconitic sandstone, Coyote Reservoir	2.25	Eocene	Paleocene
69	SSC	Rock	Tws	shale of Whitehurst Road	2.75		
69	SSC	Rock	Tws	shale of Whitehurst Road	2.75		
69	SSC	Rock	Tws	shale of Whitehurst Road	2.75		
70	MO100	Rock	PEu	sedimentary rocks, Eocene and(or) Paleocene, San Felipe	2.50	Paleocene	Createceous
71	NESF	Rock	Td	Domengine Sandstone	3.00		
72	NESF	Rock	Teh	Escobar Sandstone, basal shale member	2.50		
73	NESF	Rock	Tes	Escobar Sandstone	2.50		
74	NESF	Rock	Tmk	Markley Sandstone	2.50		
75	NESF	Rock	Tmk?	Markley Sandstone	2.50		
76	NESF	Rock	Tmkl	Markley Sandstone, lower member	2.50		
77	NESF	Rock	Tmku	Markley Sandstone, upper member	2.50		
78	NESF	Rock	Tmr	Muir Sandstone	3.25		
79	NESF	Rock	Tmr?	Muir Sandstone	3.25		
80	NESF	Rock	Tmrl	Muir Sandstone, lower member	3.25		
81	NESF	Rock	Tmru	Muir Sandstone, upper member	3.25		
82	NESF	Rock	Tnv	Kreyenhagen Formation, Nortonville Shale member	2.75	Eocene	Eocene
83	NESF	Rock	Tnvl	Kreyenhagen Formation, Nortonville Shale member, lower member	2.75	Eocene	Eocene
84	NESF	Rock	Tnvm	Kreyenhagen Formation, Nortonville	2.75	Eocene	Eocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				Shale member, middle member			
85	NESF	Rock	Tnvu	Kreyenhagen Formation, Nortonville Shale member, upper member	2.75	Eocene	Eocene
86	NESF	Rock	Tsh	shale, Eocene, Vacaville	3.00	Eocene	Eocene
87	PR	Rock	Tpr	Point Reyes Conglomerate of Galloway (1977)	1.50		
87	PR	Rock	Tpr	Point Reyes Conglomerate of Galloway (1977)	1.50		
87	PR	Rock	Tpr	Point Reyes Conglomerate of Galloway (1977)	1.50		
88	AL_CC	Rock	Td	Domengine Formation	3.00		
89	AL_CC	Rock	Tdl	Domengine Formation, lower member	3.25		
90	AL_CC	Rock	Tdls	Domengine Formation, lower member, sandstone	3.00		
91	AL_CC	Rock	Tdu	Domengine Formation, upper member	2.50		
92	AL_CC	Rock	Teh	Escobar Sandstone, basal shale member	2.50		
93	AL_CC	Rock	Tehs	Escobar Sandstone, sandstone and shale member	2.50		
94	AL_CC	Rock	Tes	Escobar Sandstone (cc/oak)	2.50		
95	AL_CC	Rock	Tes?	Escobar Sandstone?	2.50		
96	AL_CC	Rock	Tll	Markley Formation, lower member, lower siltstone beds	3.25		
97	AL_CC	Rock	Tlu	Markely Formation, lower member, upper siltstone beds	3.25		
98	AL_CC	Rock	Tmk	Markley Sandstone	2.50		
99	AL_CC	Rock	Tmkl	Markley Sandstone, lower member	2.50		
100	AL_CC	Rock	Tmku	Markely Sandstone, upper member	2.50		
101	AL_CC	Rock	Tmku?	Markely Sandstone, upper member	2.50		
102	AL_CC	Rock	Tmr	Muir Sandstone	3.25		
103	AL_CC	Rock	Tmrl	Muir Sandstone, lower claystone member	3.25		
104	AL_CC	Rock	Tmru	Muir Sandstone, upper member	3.25		
105	AL_CC	Rock	Tnv	Nortonville Shale	3.00		
106	AL_CC	Rock	Tsl	Markley Sandstone, Sidney Flat Shale, lower member	3.50		
107	AL_CC	Rock	Tsu	Markley Sandstone, Sidney Flat Shale, upper member	3.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
108	AL_CC	Rock	Tte	Tesla Formation	3.00		
109	AL_CC	Rock	Ttls	Tolman Formation, limestone	2.00		
110	AL_CC	Rock	Tts	Tolman Formation, glauconitic sandstone (al)	2.50		
111	SM	Rock	Tw	Whiskey Hill Formation	3.00		
111	SM	Rock	Tw	Whiskey Hill Formation	3.00		
111	SM	Rock	Tw	Whiskey Hill Formation	3.00		
112	PA100	Rock	Tb	Butano Sandstone	1.50		
112	PA100	Rock	Tb	Butano Sandstone	1.50		
113	PA100	Rock	Tbl	Butano Sandstone, lower conglomerate and sandstone member	2.50		
113	PA100	Rock	Tbl	Butano Sandstone, lower conglomerate and sandstone member	2.50		
114	PA100	Rock	Tblc	Butano Sandstone, lower member, conglomerate	2.50		
114	PA100	Rock	Tblc	Butano Sandstone, lower member, conglomerate	2.50		
114	PA100	Rock	Tblc	Butano Sandstone, lower member, conglomerate	2.50		
115	PA100	Rock	Tblc?	Butano Sandstone, lower member, conglomerate	2.50		
115	PA100	Rock	Tblc?	Butano Sandstone, lower member, conglomerate	2.50		
115	PA100	Rock	Tblc?	Butano Sandstone, lower member, conglomerate	2.50		
116	PA100	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
116	PA100	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
116	PA100	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
117	PA100	Rock	Tbs	Butano Sandstone, shale interbed	2.50		
117	PA100	Rock	Tbs	Butano Sandstone, shale interbed	2.50		
117	PA100	Rock	Tbs	Butano Sandstone, shale interbed	2.50		
118	PA100	Rock	Tbu	Butano Sandstone, upper sandstone member	2.50		
118	PA100	Rock	Tbu	Butano Sandstone, upper sandstone	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				member			
118	PA100	Rock	Tbu	Butano Sandstone, upper sandstone member	2.50		
119	PA100	Rock	Tst	San Lorenzo Formation, Twobar Shale Member	3.50		
119	PA100	Rock	Tst	San Lorenzo Formation, Twobar Shale Member	3.50		
119	PA100	Rock	Tst	San Lorenzo Formation, Twobar Shale Member	3.50		
120	PA100	Rock	Tu	unnamed sedimentary rocks, Eocene?, San Andreas rift zone	2.75		
120	PA100	Rock	Tu	unnamed sedimentary rocks, Eocene?, San Andreas rift zone	2.75		
120	PA100	Rock	Tu	unnamed sedimentary rocks, Eocene?, San Andreas rift zone	2.75		
121	PA100	Rock	Tw	Whiskey Hill Formation	3.00		
121	PA100	Rock	Tw	Whiskey Hill Formation	3.00		
121	PA100	Rock	Tw	Whiskey Hill Formation	3.00		
122	PA100	Rock	Tws	Whiskey Hill Formation, shale	2.75		
122	PA100	Rock	Tws	Whiskey Hill Formation, shale	2.75		
122	PA100	Rock	Tws	Whiskey Hill Formation, shale	2.75		
123	SJ100	Rock	Tbm	brown-weathering mudstone, Eocene, Coyote Reservoir	2.75		
123	SJ100	Rock	Tbm	brown-weathering mudstone, Eocene, Coyote Reservoir	2.75		
123	SJ100	Rock	Tbm	brown-weathering mudstone, Eocene, Coyote Reservoir	2.75		
124	SSC	Rock	Tmss	sandstone of Mount Madonna area	2.50		
124	SSC	Rock	Tmss	sandstone of Mount Madonna area	2.50		
124	SSC	Rock	Tmss	sandstone of Mount Madonna area	2.50		
125	SC	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
125	SC	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
125	SC	Rock	Tbm	Butano Sandstone, middle siltstone member	2.50		
126	SC	Rock	Tmm	sandstone of Mount Madonna area	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
126	SC	Rock	Tmm	sandstone of Mount Madonna area	2.50		
126	SC	Rock	Tmm	sandstone of Mount Madonna area	2.50		
127	OAK	Rock	Tes	Unnamed mudstone	2.75	Eocene	Eocene
128	OAK	Rock	Tes?	Unnamed mudstone, identification uncertain	2.75	Eocene	Eocene
129	OAK	Rock	Tmrl	Muir Sandstone, lower claystone member	3.25		
130	OAK	Rock	Tmru	Muir Sandstone, upper member	3.25		
131	OAK	Rock	Tshc	shale and claystone, Eocene	2.50	Eocene	Eocene
132	OAK	Rock	Tts	tuffaceous sandstone	2.00	Oligocene	Oligocene
133	LOMA	Rock	Tbc	Butano Sandstone Conglomerate (middle Eocene or younger)	1.50	middle Eocene	younger
134	LOMA	Rock	Tbm	Butano Sandstone, Mudstone (late Eocene)	2.50	late Eocene	late Eocene
135	LOMA	Rock	Tbs	Sandstone (middle Eocene or younger)	2.50	Eocene	middle Eocene
136	LOMA	Rock	Tbu	Undivided sandstone and shale (late to middle Eocene)	2.50	late Eocene	middle Eocene
137	LOMA	Rock	Tcm	Mottled mudstone and sandstone of Mount Chual (lower Eocene)	2.50	lower Eocene	lower Eocene
138	LOMA	Rock	Tcm?	Mottled mudstone and sandstone of Mount Chual (lower Eocene)	2.50	lower Eocene	lower Eocene
139	LOMA	Rock	Tcml	Limestone	1.50	lower Eocene	lower Eocene
140	LOMA	Rock	Tcms	Sandstone lenses	2.50	lower Eocene	lower Eocene
141	LOMA	Rock	Tlm	Siliceous mudstone	2.50		
142	LOMA	Rock	Tlm?	Siliceous mudstone	2.50		
143	LOMA	Rock	Tls	Sandstone and mudstone	2.50		
144	LOMA	Rock	Tls?	Sandstone and mudstone	2.50		
145	LOMA	Rock	Tst	Twobar Shale Member (late Eocene)	3.00	late Eocene	late Eocene
146	MO100	Rock	Ebu	Unnamed Eocene sedimentary rocks, Pajaro River	2.50	Eocene	Eocene
147	MO100	Rock	Ebu?	Unnamed Eocene sedimentary rocks, Pajaro River	2.75	Eocene	Eocene
148	MO100	Rock	Ec	Carmelo Formation	2.50	Eocene	Eocene
149	MO100	Rock	Ed	Domengine Sandstone	3.00	Eocene	Eocene
150	MO100	Rock	Ek	Kreyenhagen Formation	2.75	Eocene	Eocene
151	MO100	Rock	Elc	Cantua Sandstone	2.50	Eocene	Eocene
152	MO100	Rock	Elm	Los Muertos Formation	2.50	Eocene	Eocene

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
153	MO100	Rock	Elm?	Los Muertos Formation	2.50	Eocene	Eocene
154	MO100	Rock	Ess	Arkosic sandstone	2.50	Eocene	Eocene
155	MO100	Rock	Etp	Tres Pinos Sandstone	2.50		
156	CORD_GEO8	Rock	Td	Domengine Formation	3.00	Eocene	Eocene
157	CORD_GEO8	Rock	Td?	Domengine Formation?	3.00	Eocene	Eocene
158	CORD_GEO8	Rock	Tmk	Markley Formation. Gray to yellow-brown, micaceous marine arkosic	3.00	Eocene	Eocene
159	CORD_GEO8	Rock	Tmkj	Markley Formation, Jameson Canyon Shale Member. Well-bedded to lam	2.50	Eocene	Eocene
160	CORD_GEO8	Rock	Tn	Nortonville Shale Member of Kreyenhagen Formation	3.00	Eocene	Eocene
161	CORD_GEO8	Rock	Tn?	Nortonville Shale Member of Kreyenhagen Formation	3.00	Eocene	Eocene
162	FAIR_GEO3	Rock	Td	Domengine Formation	3.00	Eocene	Eocene
163	FAIR_GEO3	Rock	Tmk	Markley Formation. Gray to yellow-brown, micaceous marine arkosic	3.00	Eocene	Eocene
164	FAIR_GEO3	Rock	Tn	Nortonville Shale Member of Kreyenhagen Formation	3.00	Eocene	Eocene
165		Rock	Tes	mudstone, Eocene, Oakland Hills (al/oak)	2.50		
166	NESF	Rock	fsr	Franciscan melange	1.50		
167	ESWN	Rock	ch	Franciscan melange, chert block	1.50		
168	ESWN	Rock	fsr	Franciscan melange	1.50		
169	ESWN	Rock	gs	Franciscan melange, greenstone block	1.50		
170	ESWN	Rock	gs?	Franciscan melange, graywacke block	2.00		
171	ESWN	Rock	m	Franciscan melange, metamorphic block	1.50		
172	WSO	Rock	ch	Franciscan melange, chert block	1.50		
173	WSO	Rock	fsr	Franciscan melange	3.00		
174	WSO	Rock	fsr?	Franciscan melange, identification uncertain	3.00		
175	WSO	Rock	gs	Franciscan melange, greenstone block	1.50		
176	WSO	Rock	gwy	Franciscan melange, graywacke block	2.00		
177	WSO	Rock	m	Franciscan melange, high-grade metamorphic block	1.50		
178	MA	Rock	fsr	Franciscan complex, melange	3.00		
179	MA	Rock	KJfgc	Franciscan complex, greenstone and chert	1.50		
180	AL_CC	Rock	fc	Franciscan melange, chert block	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
181	AL_CC	Rock	fg	Franciscan melange, greenstone block	1.50		
182	AL_CC	Rock	fl	Franciscan melange, limestone block	1.50		
183	AL_CC	Rock	fm	Franciscan melange, schist block	2.00		
184	AL_CC	Rock	fs	Franciscan melange, graywacke block	2.00		
185	AL_CC	Rock	KJfm	Franciscan melange	3.00		
186	SFS	Rock	KJu	Franciscan melange	3.00		
186	SFS	Rock	KJu	Franciscan melange	3.00		
186	SFS	Rock	KJu	Franciscan melange	3.00		
187	SM	Rock	fsr	Franciscan melange	3.00		
187	SM	Rock	fsr	Franciscan melange	3.00		
187	SM	Rock	fsr	Franciscan melange	3.00		
188	PA100	Rock	fm	Franciscan melange, high-grade metamorphic block	1.50		
188	PA100	Rock	fm	Franciscan melange, high-grade metamorphic block	1.50		
188	PA100	Rock	fm	Franciscan melange, high-grade metamorphic block	1.50		
189	PA100	Rock	fsr	Franciscan melange	3.00		
189	PA100	Rock	fsr	Franciscan melange	3.00		
189	PA100	Rock	fsr	Franciscan melange	3.00		
190	SJ100	Rock	bl	Franciscan melange, blueschist block	1.50		
190	SJ100	Rock	bl	Franciscan melange, blueschist block	1.50		
190	SJ100	Rock	bl	Franciscan melange, blueschist block	1.50		
191	SJ100	Rock	cg	Franciscan melange, conglomerate block	1.50		
191	SJ100	Rock	cg	Franciscan melange, conglomerate block	1.50		
191	SJ100	Rock	cg	Franciscan melange, conglomerate block	1.50		
192	SJ100	Rock	ch	Franciscan melange, chert block	1.50		
192	SJ100	Rock	ch	Franciscan melange, chert block	1.50		
192	SJ100	Rock	ch	Franciscan melange, chert block	1.50		
193	SJ100	Rock	fm	Franciscan melange	3.00		
193	SJ100	Rock	fm	Franciscan melange	3.00		
193	SJ100	Rock	fm	Franciscan melange	3.00		
194	SJ100	Rock	fm?	Franciscan melange	3.00		
194	SJ100	Rock	fm?	Franciscan melange	3.00		
194	SJ100	Rock	fm?	Franciscan melange	3.00		
195	SJ100	Rock	gs	Franciscan melange, greenstone block	1.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
195	SJ100	Rock	gs	Franciscan melange, greenstone block	1.50		
195	SJ100	Rock	gs	Franciscan melange, greenstone block	1.50		
196	SJ100	Rock	gw	Franciscan melange, graywacke block	2.00		
196	SJ100	Rock	gw	Franciscan melange, graywacke block	2.00		
196	SJ100	Rock	gw	Franciscan melange, graywacke block	2.00		
197	SJ100	Rock	mw	Franciscan melange, metagraywacke block	2.00		
197	SJ100	Rock	mw	Franciscan melange, metagraywacke block	2.00		
197	SJ100	Rock	mw	Franciscan melange, metagraywacke block	2.00		
198	SSC	Rock	fc	Franciscan melange, chert block	1.50		
198	SSC	Rock	fc	Franciscan melange, chert block	1.50		
198	SSC	Rock	fc	Franciscan melange, chert block	1.50		
199	SSC	Rock	KJfm	Franciscan melange	3.00		
199	SSC	Rock	KJfm	Franciscan melange	3.00		
199	SSC	Rock	KJfm	Franciscan melange	3.00		
200	SSC	Rock	fs	Franciscan melange, sandstone block	2.00		
200	SSC	Rock	fs	Franciscan melange, sandstone block	2.00		
200	SSC	Rock	fs	Franciscan melange, sandstone block	2.00		
201	OAK	Rock	fc	Franciscan melange, chert block	1.50		
202	OAK	Rock	fg	Franciscan melange, greenstone block	1.50		
203	OAK	Rock	fm	Franciscan melange, schist block	2.00		
204	OAK	Rock	fs	Franciscan melange, graywacke block	2.00		
205	OAK	Rock	KJfm	Franciscan melange	1.50		
206	LOMA	Rock	am	Amphibolite blocks	1.50		
207	LOMA	Rock	bs	Blueschist blocks	1.50		
208	LOMA	Rock	cg	Franciscan complex, conglomerate	1.50		
209	LOMA	Rock	ch	Chert blocks	2.00		
210	LOMA	Rock	fm	Melange of the Central belt	3.00		
211	LOMA	Rock	fm?	Melange of the Central belt, identification uncertain	3.00		
212	LOMA	Rock	mdi	Metadiorite block	1.00		
213	LOMA	Rock	v	Basaltic volcanic rock blocks	1.50		
214	MO100	Rock	bs	Franciscan melange, blueschist block	1.50		
215	MO100	Rock	KJf	Franciscan Complex	1.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
216	MO100	Rock	KJfm	Franciscan Complex, melange	3.00		
217	MWS	Rock	bls	Franciscan Complex, Blueschist	1.50	Upper Cretaceous	Lower Jurassic
218	MWS	Rock	ms	Franciscan Complex, Metasandstone	1.50	Upper Cretaceous	Lower Jurassic
219	MWS	Rock	mv	Franciscan Complex, Metabasalt	1.50	Upper Cretaceous	Lower Jurassic
220	TR_GEO4	Rock	KJfm	Franciscan Complex melange. Tectonic mixture of masses of resistan	3.00		
221	PE_GEO10	Rock	KJfm	Franciscan Complex melange. Tectonic mixture of masses of resistan	3.00		
221	PE_GEO10	Rock	KJfm	Franciscan Complex melange. Tectonic mixture of masses of resistan	3.00		
221	PE_GEO10	Rock	KJfm	Franciscan Complex melange. Tectonic mixture of masses of resistan	3.00		
222	NOVA_GEO9	Rock	ch	Franciscan melange, chert block	1.50		
223	NOVA_GEO9	Rock	gs	Franciscan melange, greenstone block	1.50		
224	NOVA_GEO9	Rock	KJfm	Franciscan Complex melange. Tectonic mixture of masses of resistan	3.00		
225	NOVA_GEO9	Rock	mv	Franciscan Complex melange, metavolcanic tectonic block	3.00		
226	NOVA_GEO9	Rock	ss	Franciscan Complex melange, sandstone tectonic block	3.00		
227	WSO	Rock	Jfgs	Franciscan Complex, greenstone	1.50		
228	MA	Rock	Jfg	Franciscan complex, greenstone	1.50		
229	MA	Rock	Jfgs	Franciscan complex, greenstone, Marin Headlands	1.50	Early Jurassic	Early Jurassic
230	AL_CC	Rock	KJfg	Franciscan Complex, greenstone	1.50		
231	LOMA	Rock	fmv	Basaltic volcanic rocks	1.50	Lower Jurassic	Lower Jurassic
232	LOMA	Rock	fmv?	Basaltic volcanic rocks, identification uncertain	1.50	Lower Jurassic	Lower Jurassic
233	MO100	Rock	Jhg	Salinian complex, gabbro	1.00		
234	ESWN	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
235	WSO	Rock	Jd	Great Valley complex, Coast Range ophiolite, mafic and intermediat	2.00		
236	WSO	Rock	Ju	Great Valley complex, Coast Range ophiolite, ultramafic rocks	2.00		
237	AL_CC	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
238	AL_CC	Rock	KJqd	Great Valley complex, quartz diorite, Diablo Range	2.00		
239	SM	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
239	SM	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
239	SM	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
240	PA100	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
240	PA100	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
240	PA100	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
241	SJ100	Rock	Jdw	Great Valley complex, Coast Range ophiolite, cumulate gabbro and u	2.00		
241	SJ100	Rock	Jdw	Great Valley complex, Coast Range ophiolite, cumulate gabbro and u	2.00		
241	SJ100	Rock	Jdw	Great Valley complex, Coast Range ophiolite, cumulate gabbro and u	2.00		
242	SJ100	Rock	Jic	Great Valley complex, Coast Range ophiolite, intrusive diabase, di	2.00		
242	SJ100	Rock	Jic	Great Valley complex, Coast Range ophiolite, intrusive diabase, di	2.00		
242	SJ100	Rock	Jic	Great Valley complex, Coast Range ophiolite, intrusive diabase, di	2.00		
243	OAK	Rock	Jgb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
244	LOMA	Rock	dbc	Diabase of Corralitos Creek (lower Miocene or Jurassic)	1.00	lower Miocene	Jurassic
245	LOMA	Rock	dbc?	Diabase of Corralitos Creek? (lower Miocene or Jurassic)?	1.00	lower Miocene	Jurassic
246	LOMA	Rock	dbm	Diabase and gabbro of Morrell Cutoff Road and Laurel Creek	1.00		
247	LOMA	Rock	Jdb	Diabase breccia of Mount Umunhum (Jurassic?)	1.00	Jurassic?	Jurassic?
248	LOMA	Rock	Jog	Gabbro cumulates (Jurassic)	2.00	Jurassic	Jurassic

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
249	LOMA	Rock	Joi	Intrusive complex (Jurassic)	1.00	Jurassic	Jurassic
250	LOMA	Rock	Jou	Ultramafic cumulates (Jurassic)	1.50	Jurassic	Jurassic
251	LOMA	Rock	Jou?	Ultramafic cumulates (Jurassic)	1.50	Jurassic	Jurassic
252	MO100	Rock	gb	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
253	MO100	Rock	Jgb?	Great Valley complex, Coast Range ophiolite, gabbro	2.00		
254	CORD_GEO8	Rock	Jgb	Gabbro	2.00		
255	NESF	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
256	NESF	Rock	sp?	Great Valley complex, Coast Range ophiolite, serpentinite?	2.00		
257	ESWN	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
258	ESWN	Rock	sp	Great Valley complex, serpentinite	2.00		
259	ESWN	Rock	spm	Great Valley complex, serpentinite-matrix melange	2.00		
260	WSO	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
261	WSO	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
262	WSO	Rock	spm	Great Valley complex, Coast Range ophiolite, serpentinite-matrix m	2.00		
263	MA	Rock	Jspm	Franciscan complex, massive serpentinite-Central terrane melange	2.75		
264	MA	Rock	sc	Great Valley complex, silica-carbonate rock	2.00		
265	MA	Rock	sp	Great Valley complex, serpentinite	2.00		
266	AL_CC	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
267	AL_CC	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
268	SFS	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
268	SFS	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
268	SFS	Rock	sp	Great Valley complex, Coast Range	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				ophiolite, serpentinite			
269	SM	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
269	SM	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
269	SM	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
270	PA100	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
270	PA100	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
270	PA100	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
271	SJ100	Rock	Jsp	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
271	SJ100	Rock	Jsp	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
271	SJ100	Rock	Jsp	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
272	SJ100	Rock	Jsp?	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
272	SJ100	Rock	Jsp?	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
272	SJ100	Rock	Jsp?	Great Valley complex, Coast Range ophiolite, serpentinized harzbur	2.00		
273	SJ100	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
273	SJ100	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
273	SJ100	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
274	SSC	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
274	SSC	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		
274	SSC	Rock	sc	Great Valley complex, Coast Range ophiolite, silica carbonate rock	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
275	SSC	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
275	SSC	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
275	SSC	Rock	sp	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
276	OAK	Rock	sc	Coast Range Ophiolite, silica carbonate rock	1.50		
277	OAK	Rock	sp	Coast Range Ophiolite serpentinite	1.50		
278	OAK	Rock	sp?	Coast Range Ophiolite, serpentinite?	1.50		
279	OAK	Rock	spm	Great Valley complex, Coast Range ophiolite, serpentinite matrix m	2.00		
280	LOMA	Rock	Jos	Serpentinized ultramafic rocks (Jurassic)	2.00	Jurassic	Jurassic
281	LOMA	Rock	Jos?	Serpentinized ultramafic rocks?(Jurassic)	2.00	Jurassic	Jurassic
282	LOMA	Rock	Jssp	Sedimentary serpentinite (Upper Jurassic)	2.00	Upper Jurassic	Upper Jurassic
283	LOMA	Rock	sc	Silica-carbonate rock (Miocene?)	1.00	Miocene?	Miocene?
284	LOMA	Rock	sc?	Silica-carbonate rock (Miocene?)	1.00	Miocene?	Miocene?
285	MO100	Rock	um	Great Valley complex, Coast Range ophiolite, serpentinite	2.00		
286	MWS	Rock	Jos	Franciscan Complex and Coast Range Ophiolite, Serpentinized ultram	2.00	Upper Cretaceous	Lower Jurassic
287	MWS	Rock	Jos?	Franciscan Complex and Coast Range Ophiolite, Serpentinized ultram	2.00	Upper Cretaceous	Lower Jurassic
288	MWS	Rock	sc	Silica carbonate rock	1.00		
289	PE_GEO10	Rock	sp	Serpentinized ultramafic rocks.	2.00	Jurassic	Jurassic
289	PE_GEO10	Rock	sp	Serpentinized ultramafic rocks.	2.00	Jurassic	Jurassic
289	PE_GEO10	Rock	sp	Serpentinized ultramafic rocks.	2.00	Jurassic	Jurassic
290	NOVA_GEO9	Rock	sp	Serpentinized ultramafic rocks.	2.00	Jurassic	Jurassic
291	CORD_GEO8	Rock	sc	Silica carbonate rock	1.00		
292	CORD_GEO8	Rock	sp	Serpentinized ultramafic rocks.	2.00	Jurassic	Jurassic
293	NESF	Rock	Jb	Great Valley complex, Coast Range ophiolite, massive and pillow ba	2.00		
294	NESF	Rock	Jsv	Great Valley complex, keratophyre (Jurassic)	2.00		
295	NESF	Rock	Jv	Great Valley complex, Coast Range ophiolite, basalt and keratophyr	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
296	ESWN	Rock	Jmi	Great Valley complex, Coast Range ophiolite, mafic intrusive compl	2.00		
297	ESWN	Rock	Jv	Great Valley complex, Coast Range ophiolite, basalt	2.00		
298	WSO	Rock	Jsv	Great Valley complex, keratophyre and quartz keratophyre	2.00		
299	WSO	Rock	Jv	Great Valley complex, Coast Range ophiolite, mafic and intermediat	2.00		
300	WSO	Rock	KJsb	Great Valley complex?, Coast Range ophiolite?, spillite of Black P	2.00		
301	MA	Rock	Kfdb	Franciscan complex, diabase- Permanente terrane	1.50		
302	AL_CC	Rock	Jb	Great Valley complex, Coast Range ophiolite, basalt and diabase	2.00		
303	AL_CC	Rock	Jdb	Great Valley complex, Coast Range ophiolite, diabase	2.00		
304	AL_CC	Rock	Jpb	Great Valley complex, Coast Range ophiolite, pillow basalt	2.00		
305	PA100	Rock	db	Great Valley complex, diabase	2.00		
305	PA100	Rock	db	Great Valley complex, diabase	2.00		
305	PA100	Rock	db	Great Valley complex, diabase	2.00		
306	PA100	Rock	Jsv	Great Valley complex, siliceous volcanic rocks and keratophyre	2.00		
306	PA100	Rock	Jsv	Great Valley complex, siliceous volcanic rocks and keratophyre	2.00		
306	PA100	Rock	Jsv	Great Valley complex, siliceous volcanic rocks and keratophyre	2.00		
307	SJ100	Rock	Jbk	Great Valley complex, Coast Range ophiolite, basalt and keratophyr	2.00		
307	SJ100	Rock	Jbk	Great Valley complex, Coast Range ophiolite, basalt and keratophyr	2.00		
307	SJ100	Rock	Jbk	Great Valley complex, Coast Range ophiolite, basalt and keratophyr	2.00		
308	OAK	Rock	Jb	Great Valley complex, Coast Range ophiolite, basalt and diabase	2.00		
309	OAK	Rock	Jpb	Great Valley complex, Coast Range ophiolite, pillow basalt	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
310	OAK	Rock	Jpb?	Great Valley complex, Coast Range ophiolite, pillow basalt?	2.00		
311	OAK	Rock	Jsv	Coast Range Ophiolite, keratophyre	2.00		
312	LOMA	Rock	Jov	Basalt, andesite, and dacite (Middle Jurassic or older)	1.50	Middle Jurassic	Older
313	LOMA	Rock	Jov?	Basalt, andesite, and dacite (Middle Jurassic or older)	1.50	Middle Jurassic	Older
314	LOMA	Rock	Jovb	Quartz-keratophyre breccia and siliceous tuff (Upper and Middle Ju	1.00	Upper Jurassic	Middle Jurassic
315	LOMA	Rock	Jt	Altered tuff of Mount Umunhum (Jurassic?)	2.00	Jurassic?	Jurassic?
316	CORD_GEO8	Rock	Jv	Keratophyre	2.00		
317	MA	Rock	Kfl	Franciscan complex, limestone and chert-Permanente terrane	1.50		
318	SJ100	Rock	fbc	Franciscan complex, Burnt Hills terrane, chert	1.50		
318	SJ100	Rock	fbc	Franciscan complex, Burnt Hills terrane, chert	1.50		
318	SJ100	Rock	fbc	Franciscan complex, Burnt Hills terrane, chert	1.50		
319	NESF	Rock	KJfm	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
320	NESF	Rock	KJfm?	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
321	AL_CC	Rock	KJfe	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
322	SJ100	Rock	fb2	Franciscan complex, Burnt Hills terrane, middle	1.50		
322	SJ100	Rock	fb2	Franciscan complex, Burnt Hills terrane, middle	1.50		
322	SJ100	Rock	fb2	Franciscan complex, Burnt Hills terrane, middle	1.50		
323	SJ100	Rock	fy1	Franciscan Complex, Yolla Bolly terrane, metagraywacke, uncleaved	2.00		
323	SJ100	Rock	fy1	Franciscan Complex, Yolla Bolly terrane, metagraywacke, uncleaved	2.00		
323	SJ100	Rock	fy1	Franciscan Complex, Yolla Bolly terrane,	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				metagraywacke, uncleaved			
324	SJ100	Rock	fy1?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, uncleaved	2.00		
324	SJ100	Rock	fy1?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, uncleaved	2.00		
324	SJ100	Rock	fy1?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, uncleaved	2.00		
325	SJ100	Rock	fy2	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
325	SJ100	Rock	fy2	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
325	SJ100	Rock	fy2	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
326	SJ100	Rock	fy2?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
326	SJ100	Rock	fy2?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
326	SJ100	Rock	fy2?	Franciscan Complex, Yolla Bolly terrane, metagraywacke, irregularl	2.00		
327	SJ100	Rock	fy3	Franciscan Complex, Yolla Bolly terrane, metagraywacke, cleaved	2.00		
327	SJ100	Rock	fy3	Franciscan Complex, Yolla Bolly terrane, metagraywacke, cleaved	2.00		
327	SJ100	Rock	fy3	Franciscan Complex, Yolla Bolly terrane, metagraywacke, cleaved	2.00		
328	SJ100	Rock	fyc	Franciscan Complex, Yolla Bolly terrane, chert and metachert	1.50		
328	SJ100	Rock	fyc	Franciscan Complex, Yolla Bolly terrane, chert and metachert	1.50		
328	SJ100	Rock	fyc	Franciscan Complex, Yolla Bolly terrane, chert and metachert	1.50		
329	SJ100	Rock	fyg	Franciscan Complex, Yolla Bolly terrane, greenstone and bluestone	1.50		
329	SJ100	Rock	fyg	Franciscan Complex, Yolla Bolly terrane, greenstone and bluestone	1.50		
329	SJ100	Rock	fyg	Franciscan Complex, Yolla Bolly terrane, greenstone and bluestone	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
330	SJ100	Rock	fys	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
330	SJ100	Rock	fys	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
330	SJ100	Rock	fys	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
331	SJ100	Rock	fyu	Franciscan Complex, Yolla Bolly terrane	2.00		
331	SJ100	Rock	fyu	Franciscan Complex, Yolla Bolly terrane	2.00		
331	SJ100	Rock	fyu	Franciscan Complex, Yolla Bolly terrane	2.00		
332	SSC	Rock	KJfy	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
332	SSC	Rock	KJfy	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
332	SSC	Rock	KJfy	Franciscan Complex, Yolla Bolly terrane, metagraywacke	2.00		
333	OAK	Rock	KJfy	Franciscan complex, metasandstone of the Yolla Bolly terrane	1.50		
334	NESF	Rock	Kfs	Franciscan Complex, Novato Quarry terrane, graywacke	2.00		
335	ESWN	Rock	Kfss	Franciscan Complex, sandstone	2.00		
336	WSO	Rock	Kfgwy	Franciscan Complex, Marin Headlands terrane, sandstone	2.00		
337	WSO	Rock	Kfss	Franciscan Complex, sandstone, Cretaceous	2.00	Late Createcous (ca	Late Createcous
338	MA	Rock	Kfgwy	Franciscan complex, graywacke, Marin Headlands and Nicasio Reservo	2.00	Cretaceous	Cretaceous
339	MA	Rock	Kfs	Franciscan complex, sandstone and shale-San Bruno Mountain and No	2.00		
340	MA	Rock	Kfsh	Franciscan complex, thin-bedded shale	2.25		
341	MA	Rock	Kfss	Franciscan complex, massive sandstone	2.00		
342	AL_CC	Rock	Kfn	Franciscan Complex, Novato Quarry terrane, graywacke	2.00		
343	SM	Rock	fcg	Franciscan Complex, conglomerate	1.50		
343	SM	Rock	fcg	Franciscan Complex, conglomerate	1.50		
343	SM	Rock	fcg	Franciscan Complex, conglomerate	1.50		
344	SM	Rock	fl	Franciscan Complex, Permanente terrane,	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				limestone			
344	SM	Rock	fl	Franciscan Complex, Permanente terrane, limestone	1.50		
344	SM	Rock	fl	Franciscan Complex, Permanente terrane, limestone	1.50		
345	PA100	Rock	fh	Franciscan Complex, argillite	2.50		
345	PA100	Rock	fh	Franciscan Complex, argillite	2.50		
345	PA100	Rock	fh	Franciscan Complex, argillite	2.50		
346	PA100	Rock	fl	Franciscan Complex, limestone	1.50		
346	PA100	Rock	fl	Franciscan Complex, limestone	1.50		
346	PA100	Rock	fl	Franciscan Complex, limestone	1.50		
347	SJ100	Rock	fb1	Franciscan complex, Burnt Hills terrane, lower	1.50		
347	SJ100	Rock	fb1	Franciscan complex, Burnt Hills terrane, lower	1.50		
347	SJ100	Rock	fb1	Franciscan complex, Burnt Hills terrane, lower	1.50		
348	SJ100	Rock	fb1?	Franciscan complex, Burnt Hills terrane, lower	1.50		
348	SJ100	Rock	fb1?	Franciscan complex, Burnt Hills terrane, lower	1.50		
348	SJ100	Rock	fb1?	Franciscan complex, Burnt Hills terrane, lower	1.50		
349	SSC	Rock	Kfms	Franciscan Complex, Marin Headlands terrane, sandstone	2.00		
349	SSC	Rock	Kfms	Franciscan Complex, Marin Headlands terrane, sandstone	2.00		
349	SSC	Rock	Kfms	Franciscan Complex, Marin Headlands terrane, sandstone	2.00		
350	SSC	Rock	Kfpl	Franciscan Complex, Permanente terrane, limestone	1.50		
350	SSC	Rock	Kfpl	Franciscan Complex, Permanente terrane, limestone	1.50		
350	SSC	Rock	Kfpl	Franciscan Complex, Permanente terrane, limestone	1.50		
351	SSC	Rock	Kfps	Franciscan Complex, Permanente terrane, sandstone	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
351	SSC	Rock	Kfps	Franciscan Complex, Permanente terrane, sandstone	2.00		
351	SSC	Rock	Kfps	Franciscan Complex, Permanente terrane, sandstone	2.00		
352	OAK	Rock	Kfa	Franciscan Complex, Alcatraz terrane, graywacke	2.00		
353	OAK	Rock	Kfn	Franciscan Complex, Novato Quarry terrane, graywacke	2.00		
354	LOMA	Rock	fms	Sandstone	2.50	Upper Cretaceous	Lower Cretaceous
355	LOMA	Rock	fms?	Sandstone, identification uncertain	2.50	Upper Cretaceous	Lower Cretaceous
356	LOMA	Rock	fpl	Foraminiferal limestone	1.50		
357	PE_GEO10	Rock	KJfs	Franciscan graywacke (Jurassic-Cretaceous). Thick-bedded graywacke	2.00		
357	PE_GEO10	Rock	KJfs	Franciscan graywacke (Jurassic-Cretaceous). Thick-bedded graywacke	2.00		
357	PE_GEO10	Rock	KJfs	Franciscan graywacke (Jurassic-Cretaceous). Thick-bedded graywacke	2.00		
358	CORD_GEO8	Rock	KJfs	Franciscan graywacke (Jurassic-Cretaceous). Thick-bedded graywacke	2.00		
359	WSO	Rock	Kfg	Franciscan Complex, greenstone, Cretaceous	1.50		
360	MA	Rock	Kfg	Franciscan complex, greenstone-Permanente and Nicasio Reservoir t	1.50		
361	SJ100	Rock	fbg	Franciscan complex, Burnt Hills terrane, greenstone	1.50		
361	SJ100	Rock	fbg	Franciscan complex, Burnt Hills terrane, greenstone	1.50		
361	SJ100	Rock	fbg	Franciscan complex, Burnt Hills terrane, greenstone	1.50		
362	SSC	Rock	Kfpg	Franciscan Complex, Permanente terrane, greenstone	1.50		
362	SSC	Rock	Kfpg	Franciscan Complex, Permanente terrane, greenstone	1.50		
362	SSC	Rock	Kfpg	Franciscan Complex, Permanente terrane, greenstone	1.50		
363	OAK	Rock	Kfgm	Franciscan complex, quartz diorite of the Novato Quarry terrane	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
364	LOMA	Rock	fpt	siliceous-radiolarian bearing tuff	1.50		
365	LOMA	Rock	fpv	Volcanic rocks	1.50		
366	LOMA	Rock	fpv?	Volcanic rocks, identification uncertain	1.50		
367	WSO	Rock	Kgr	Quartz diorite of Bodega Head	1.00		
368	PR	Rock	Kg	Porphyritic granodiorite of Point Reyes	1.00		
368	PR	Rock	Kg	Porphyritic granodiorite of Point Reyes	1.00		
368	PR	Rock	Kg	Porphyritic granodiorite of Point Reyes	1.00		
369	PR	Rock	Kgr	Granodiorite and granite of Inverness Ridge	1.00		
369	PR	Rock	Kgr	Granodiorite and granite of Inverness Ridge	1.00		
369	PR	Rock	Kgr	Granodiorite and granite of Inverness Ridge	1.00		
370	PR	Rock	Kqd	Tonalite of Tomales Point	1.00		
370	PR	Rock	Kqd	Tonalite of Tomales Point	1.00		
370	PR	Rock	Kqd	Tonalite of Tomales Point	1.00		
371	SM	Rock	Kgr	Salinian complex, granitic rocks, Montara Mountain	1.00		
371	SM	Rock	Kgr	Salinian complex, granitic rocks, Montara Mountain	1.00		
371	SM	Rock	Kgr	Salinian complex, granitic rocks, Montara Mountain	1.00		
372	PA100	Rock	ga	Salinian complex, granite and alaskite, Ben Lomond Mountain	1.00		
372	PA100	Rock	ga	Salinian complex, granite and alaskite, Ben Lomond Mountain	1.00		
372	PA100	Rock	ga	Salinian complex, granite and alaskite, Ben Lomond Mountain	1.00		
373	PA100	Rock	hcg	Salinian complex, hornblende-cumingtonite gabbro, Ben Lomond Mount	1.00		
373	PA100	Rock	hcg	Salinian complex, hornblende-cumingtonite gabbro, Ben Lomond Mount	1.00		
373	PA100	Rock	hcg	Salinian complex, hornblende-cumingtonite gabbro, Ben Lomond Mount	1.00		
374	PA100	Rock	Kgr	granitic rocks, Montara Mountain	1.00		
374	PA100	Rock	Kgr	granitic rocks, Montara Mountain	1.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
374	PA100	Rock	Kgr	granitic rocks, Montara Mountain	1.00		
375	PA100	Rock	Kqd	granitic rocks, Ben Lomond Mountain	1.00		
375	PA100	Rock	Kqd	granitic rocks, Ben Lomond Mountain	1.00		
375	PA100	Rock	Kqd	granitic rocks, Ben Lomond Mountain	1.00		
376	SC	Rock	hcg	Salinian complex, hornblende-cummingtonite gabbro, Ben Lomond Mt	1.00		
376	SC	Rock	hcg	Salinian complex, hornblende-cummingtonite gabbro, Ben Lomond Mt	1.00		
376	SC	Rock	hcg	Salinian complex, hornblende-cummingtonite gabbro, Ben Lomond Mt	1.00		
377	LOMA	Rock	Kgr	Granitic and metamorphic rocks (Cretaceous and older)	1.00	Cretaceous	Older
378	MO100	Rock	Kgd	Salinian complex, granodiorite	1.00		
379	MO100	Rock	Kgr	Salinian complex, granite	1.00		
380	MO100	Rock	Kgr?	Salinian complex, granite?	1.00		
381	MO100	Rock	Kqd	Salinian complex, quartz diorite	1.00		
382	MO100	Rock	Kqm	Salinian complex, quartz monzonite	1.00		
383	FA	Rock	Kgr	Granitic rocks	1.00		
384	WSO	Rock	KJfc	Franciscan Complex, chert	1.50	Createcous	Jurassic
385	MA	Rock	KJfch	Franciscan complex, chert, Marin Headlands and Nicasio Reservoir t	1.50	Cretacous	Early Jurassic
386	SFS	Rock	KJc	Franciscan Complex, chert	1.50		
386	SFS	Rock	KJc	Franciscan Complex, chert	1.50		
386	SFS	Rock	KJc	Franciscan Complex, chert	1.50		
387	SM	Rock	fc	Franciscan Complex, chert	1.50		
387	SM	Rock	fc	Franciscan Complex, chert	1.50		
387	SM	Rock	fc	Franciscan Complex, chert	1.50		
388	PA100	Rock	fc	Franciscan Complex, chert	1.50		
388	PA100	Rock	fc	Franciscan Complex, chert	1.50		
388	PA100	Rock	fc	Franciscan Complex, chert	1.50		
389	SSC	Rock	KJfmc	Franciscan Complex, Marin Headlands terrane, chert	1.50		
389	SSC	Rock	KJfmc	Franciscan Complex, Marin Headlands terrane, chert	1.50		
389	SSC	Rock	KJfmc	Franciscan Complex, Marin Headlands terrane, chert	1.50		
390	LOMA	Rock	fmc	Radiolarian chert	1.50	Lower Creteacous	Jurassic

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
391	LOMA	Rock	fmc?	Radiolarian chert, identification uncertain	1.50	Lower Creteacous	Jurassic
392	MO100	Rock	ch	Franciscan complex, chert	1.50		
393	MWS	Rock	fcc	Franciscan Complex, Radiolarian chert of Marin Headlands-Geysers t	1.50	Upper Cretaceous	Lower Jurassic
394	ESWN	Rock	Jfmch	Franciscan Complex, metachert	1.50		
395	ESWN	Rock	Jfmgs	Franciscan Complex, metagreenstone	1.50		
396	ESWN	Rock	KJfm	Franciscan Complex, metagraywacke	2.00		
397	ESWN	Rock	KJfm?	Franciscan Complex, metagraywacke	2.00		
398	WSO	Rock	KJfm	Franciscan Complex, metagraywacke	2.00	Createcous	Jurassic
399	WSO	Rock	KJfmg	Franciscan Complex, greenstone	1.50	Createcous	Jurassic
400	MA	Rock	Jfmch	Franciscan complex, metachert, Yolla Bolla	1.50	Late Jurssaic	Early (?) Jurassic
401	MA	Rock	Jfmg	Franciscan complex, metamorphic rocks, gneissic- Central terrane m	1.50		
402	MA	Rock	Jfmgc	Franciscan complex, meta-greenstone and metachert- Central terrane	1.50		
403	MA	Rock	Jfmgs	Franciscan complex, meta-greenstone, Yolla Bolla	1.50	Early (?) Jurassic	Early (?) Jurassic
404	MA	Rock	KJfm	Franciscan complex, meta-graywacke	2.00		
405	SFS	Rock	KJm	Franciscan Complex, metamorphic rocks	1.50		
405	SFS	Rock	KJm	Franciscan Complex, metamorphic rocks	1.50		
405	SFS	Rock	KJm	Franciscan Complex, metamorphic rocks	1.50		
406	SM	Rock	fm	Franciscan Complex, metamorphic rocks	1.50		
406	SM	Rock	fm	Franciscan Complex, metamorphic rocks	1.50		
406	SM	Rock	fm	Franciscan Complex, metamorphic rocks	1.50		
407	SJ100	Rock	as	antigorite schist	1.50		
407	SJ100	Rock	as	antigorite schist	1.50		
407	SJ100	Rock	as	antigorite schist	1.50		
408	SJ100	Rock	fws	Franciscan Complex, Ward Creek (Cazadero) terrane, schist	2.00		
408	SJ100	Rock	fws	Franciscan Complex, Ward Creek (Cazadero) terrane, schist	2.00		
408	SJ100	Rock	fws	Franciscan Complex, Ward Creek (Cazadero) terrane, schist	2.00		
409	PE_GEO10	Rock	KJfsch	Franciscan Complex schist, phyllite, and semischist.	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
409	PE_GEO10	Rock	KJfsch	Franciscan Complex schist, phyllite, and semischist.	2.50		
409	PE_GEO10	Rock	KJfsch	Franciscan Complex schist, phyllite, and semischist.	2.50		
410	NOVA_GEO9	Rock	KJfsch	Franciscan Complex schist, phyllite, and semischist.	2.50		
411	ESWN	Rock	KJfs	Francsican Complex, graywacke and melange	2.00		
412	WSO	Rock	KJfs	Franciscan Complex, graywacke and melange	2.00	Createcous	Jurassic
413	MA	Rock	fs?	Franciscan Complex, sandstone, identification uncertain	2.00		
414	AL_CC	Rock	fss	Franciscan Complex, sandstone and shale	2.00		
415	AL_CC	Rock	KJf	Franciscan Complex	1.50		
416	SFS	Rock	KJs	Franciscan Complex, sandstone and shale	2.00		
416	SFS	Rock	KJs	Franciscan Complex, sandstone and shale	2.00		
416	SFS	Rock	KJs	Franciscan Complex, sandstone and shale	2.00		
417	SFS	Rock	KJs?	Franciscan Complex, sandstone and shale	2.00		
417	SFS	Rock	KJs?	Franciscan Complex, sandstone and shale	2.00		
417	SFS	Rock	KJs?	Franciscan Complex, sandstone and shale	2.00		
418	SFS	Rock	KJsk	Franciscan Complex, sandstone and shale, >2% K-spar	2.00		
418	SFS	Rock	KJsk	Franciscan Complex, sandstone and shale, >2% K-spar	2.00		
418	SFS	Rock	KJsk	Franciscan Complex, sandstone and shale, >2% K-spar	2.00		
419	SM	Rock	fs	Franciscan Complex, sandstone	2.00		
419	SM	Rock	fs	Franciscan Complex, sandstone	2.00		
419	SM	Rock	fs	Franciscan Complex, sandstone	2.00		
420	SM	Rock	KJf	Franciscan Complex, undivided	1.50		
420	SM	Rock	KJf	Franciscan Complex, undivided	1.50		
420	SM	Rock	KJf	Franciscan Complex, undivided	1.50		
421	PA100	Rock	fs	Franciscan Complex, sandstone	2.00		
421	PA100	Rock	fs	Franciscan Complex, sandstone	2.00		
421	PA100	Rock	fs	Franciscan Complex, sandstone	2.00		
422	PA100	Rock	KJf	Franciscan Complex, undivided	1.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
422	PA100	Rock	KJf	Franciscan Complex, undivided	1.50		
422	PA100	Rock	KJf	Franciscan Complex, undivided	1.50		
423	OAK	Rock	KJf	Franciscan Complex	1.50		
424	OAK	Rock	KJfs	Franciscan complex, undivided sandstone	2.00		
425	MO100	Rock	cg	Franciscan complex, conglomerate	1.50		
426	MO100	Rock	KJfss	Franciscan Complex, sandstone	2.00		
427	MO100	Rock	ls	Franciscan complex, limestone	1.50		
428	MO100	Rock	ss	Franciscan Complex, sandstone	2.00		
429	MWS	Rock	cgl	Franciscan Complex, Conglomerate	1.50	Upper Cretaceous	Lower Jurassic
430	MWS	Rock	fcm	Franciscan Complex, Undifferentiated melange of the Central belt	3.00	Upper Cretaceous	Lower Jurassic
431	MWS	Rock	fcm?	Franciscan Complex, Undifferentiated melange of the Central belt,	3.00	Upper Cretaceous	Lower Jurassic
432	MWS	Rock	fcs2	Franciscan Complex, Sandstone, shale and conglomerate	2.00	Upper Cretaceous	Lower Jurassic
433	MWS	Rock	fcs2?	Franciscan Complex, Sandstone, shale and conglomerate, identificat	2.00	Upper Cretaceous	Lower Jurassic
434	MWS	Rock	ss	Franciscan Complex, Sandstone and shale	2.00	Upper Cretaceous	Lower Jurassic
435	NOVA_GEO9	Rock	KJfs	Franciscan graywacke (Jurassic-Cretaceous). Thick-bedded graywacke	2.00		
436	SFS	Rock	KJg	Franciscan Complex, greenstone	1.50		
436	SFS	Rock	KJg	Franciscan Complex, greenstone	1.50		
436	SFS	Rock	KJg	Franciscan Complex, greenstone	1.50		
437	SM	Rock	fg	Franciscan Complex, greenstone	1.50		
437	SM	Rock	fg	Franciscan Complex, greenstone	1.50		
437	SM	Rock	fg	Franciscan Complex, greenstone	1.50		
438	PA100	Rock	fg	Franciscan Complex, greenstone	1.50		
438	PA100	Rock	fg	Franciscan Complex, greenstone	1.50		
438	PA100	Rock	fg	Franciscan Complex, greenstone	1.50		
439	MWS	Rock	fcv	Franciscan Complex, Basalt	1.50	Upper Cretaceous	Lower Jurassic
440	MWS	Rock	gd	Franciscan Complex, Gabbro	1.50	Upper Cretaceous	Lower Jurassic
441	PE_GEO10	Rock	KJgv	Great Valley Sequence, undivided (Jurassic-Cretaceous). Sandstone,	2.00		
441	PE_GEO10	Rock	KJgv	Great Valley Sequence, undivided (Jurassic-Cretaceous). Sandstone,	2.00		
441	PE_GEO10	Rock	KJgv	Great Valley Sequence, undivided	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				(Jurassic-Cretaceous). Sandstone,			
442	NOVA_GEO9	Rock	KJgv	Great Valley Sequence, undivided (Jurassic-Cretaceous). Sandstone,	2.00		
443	WSO	Rock	KJfgc	Franciscan Complex, greenstone and chert	1.50	Createcous	Jurassic
444	AL_CC	Rock	fbc	Franciscan complex, basalt and chert	1.50		
445	MO100	Rock	gs	Franciscan melange, greenstone block	1.50		
446	WSO	Rock	KJfgcs	Franciscan Complex, greenstone, chert, and sandstone	2.00	Createcous	Jurassic
447	NESF	Rock	Jk	Great Valley complex, Knoxville Formation	2.50		
448	NESF	Rock	KJgv	Great Valley complex, lower member, sandstone and shale (L Cret	2.25	Lower Cretaceous	upper Jurassic
449	NESF	Rock	KJgvm	Great Valley complex, basal sedimentary-matrix melange	2.00		
450	NESF	Rock	KJu	Great Valley complex, lower member, sandstone member	2.00		
451	ESWN	Rock	Jk	Great Valley complex, Knoxville Formation	2.50		
452	ESWN	Rock	KJgv	Great Valley complex, sandstone, shale, conglomerate	2.00		
453	ESWN	Rock	KJgvl	Great Valley complex, lower	2.00		
454	ESWN	Rock	KJgvm	Great Valley complex, basal sedimentary-matrix melange	2.00		
455	ESWN	Rock	KJgvm?	Great Valley complex, basal sedimentary-matrix melange	2.00		
456	ESWN	Rock	KJsp	Great Valley complex, lower, serpentinite sandstone	2.00		
457	WSO	Rock	Jk	Great Valley complex, Knoxville Formation	2.50		
458	WSO	Rock	KJgv	Great Valley complex, Healdsburg terrane, sandstone, shale, and co	2.00		
459	WSO	Rock	KJgvc	Great Valley complex, Healdsburg terrane, conglomerate	2.00		
460	WSO	Rock	KJgvs	Great Valley complex, Healdsburg terrane, sandstone, siltstone, an	2.00		
461	MA	Rock	KJgv	Great Valley complex, undivided	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				sandstone, shale, and conglomerate			
462	AL_CC	Rock	KJk	Great Valley complex, Knoxville Formation	2.50		
463	AL_CC	Rock	KJk?	Great Valley complex, Knoxville Formation?	2.50		
464	AL_CC	Rock	KJkc	Great Valley complex, Knoxville Formation, conglomerate	2.00		
465	AL_CC	Rock	KJkv	Great Valley complex, Knoxville Formation, volcanoclastic breccia	2.00		
466	SJ100	Rock	Kbc	Great Valley complex, Berryessa Formation, conglomerate	2.00		
466	SJ100	Rock	Kbc	Great Valley complex, Berryessa Formation, conglomerate	2.00		
466	SJ100	Rock	Kbc	Great Valley complex, Berryessa Formation, conglomerate	2.00		
467	SJ100	Rock	Kbc?	Great Valley complex, Berryessa Formation, conglomerate	2.00		
467	SJ100	Rock	Kbc?	Great Valley complex, Berryessa Formation, conglomerate	2.00		
467	SJ100	Rock	Kbc?	Great Valley complex, Berryessa Formation, conglomerate	2.00		
468	SJ100	Rock	Kbs	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
468	SJ100	Rock	Kbs	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
468	SJ100	Rock	Kbs	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
469	SJ100	Rock	Kbs?	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
469	SJ100	Rock	Kbs?	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
469	SJ100	Rock	Kbs?	Great Valley complex, Berryessa Formation, sandstone and mudstone	2.00		
470	SJ100	Rock	KJk	Great Valley complex, Knoxville Formation	2.50		
470	SJ100	Rock	KJk	Great Valley complex, Knoxville Formation	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
470	SJ100	Rock	KJk	Great Valley complex, Knoxville Formation	2.50		
471	SJ100	Rock	KJk?	Great Valley complex, Knoxville Formation?	2.50		
471	SJ100	Rock	KJk?	Great Valley complex, Knoxville Formation?	2.50		
471	SJ100	Rock	KJk?	Great Valley complex, Knoxville Formation?	2.50		
472	SSC	Rock	Khu	Great Valley complex, sandstone, shale, conglomerate, Early? Cret.	2.00		
472	SSC	Rock	Khu	Great Valley complex, sandstone, shale, conglomerate, Early? Cret.	2.00		
472	SSC	Rock	Khu	Great Valley complex, sandstone, shale, conglomerate, Early? Cret.	2.00		
473	OAK	Rock	KJk	Great Valley complex, Knoxville Formation	2.50		
474	OAK	Rock	KJkc	Great Valley complex, Knoxville Formation, conglomerate	2.00		
475	OAK	Rock	KJkv	Great Valley complex, Knoxville Formation, volcanoclastic breccia	2.00		
476	LOMA	Rock	KJm	Mudstone (Lower Cretaceous and Upper Jurassic)	3.50	Lower Cretaceous	upper Jurassic
477	LOMA	Rock	KJm?	Mudstone (Lower Cretaceous and Upper Jurassic)	3.50	Lower Cretaceous	upper Jurassic
478	MO100	Rock	KJu	Great Valley complex, lower sedimentary rocks	2.00		
479	MO100	Rock	KJu?	Great Valley complex, lower sedimentary rocks	2.00		
480	PA100	Rock	KJv	unnamed volcanic rocks, Pigeon Point	1.50		
480	PA100	Rock	KJv	unnamed volcanic rocks, Pigeon Point	1.50		
480	PA100	Rock	KJv	unnamed volcanic rocks, Pigeon Point	1.50		
481	NESF	Rock	Kcs	Great Valley complex, massive sandstone, upper, Martinez	2.00		
482	NESF	Rock	Kf	Great Valley complex, Funks formation (Upper Cretaceous)	2.00		
483	NESF	Rock	Kfo	Great Valley complex, Forbes Formation (Upper Cretaceous)	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
484	NESF	Rock	Kg	Great Valley complex, Guinda Formation (U Cret)	2.00		
485	NESF	Rock	Kgvn	Great Valley complex, Novato Conglomerate (L Cret)	2.00		
486	NESF	Rock	Ks	Great Valley complex, Sites Formation	2.00		
487	NESF	Rock	Ks	Great Valley complex, Sites Formation	2.00		
488	NESF	Rock	Ksh	Great Valley complex, siliceous shale, Vaca Valley	2.00		
489	NESF	Rock	Ku	Great Valley complex, undivided, Martinez	2.00		
490	NESF	Rock	Ku?	Great Valley complex, undivided, Martinez	2.00		
491	NESF	Rock	Kuh	Great Valley complex, massive sandstone, lower, Martinez	2.00		
492	NESF	Rock	Kuhs	Great Valley complex, sandstone and shale, Vaca Valley	2.00		
493	NESF	Rock	Kuhs?	Great Valley complex, sandstone and shale, Vaca Valley	2.00		
494	NESF	Rock	Kus	Great Valley complex, sandstone, siltstone, and shale, Martinez	2.00		
495	NESF	Rock	Kuss	Great Valley complex, sandstone, Vaca Valley	2.00		
496	NESF	Rock	Kuss?	Great Valley complex, sandstone, Vaca Valley	2.00		
497	NESF	Rock	Kv	Great Valley complex, Venado Formation	2.00		
498	NESF	Rock	Ky	Great Valley complex, Yolo Formation	2.00		
499	ESWN	Rock	Kv	Great Valley complex, Venado Formation	2.00		
500	WSO	Rock	Ka	Great Valley complex?, Gualala Formation, Anchor Bay member	2.00		
501	WSO	Rock	Ks	Great Valley complex?, Gualala Formation, Stewarts Point member	2.00		
502	MA	Rock	Kgvn	Great Valley complex, Novato Conglomerate	2.00		
503	AL_CC	Rock	Ka	Great Valley complex, unit A, shale	2.50		
504	AL_CC	Rock	Ka?	Great Valley complex, unit A, shale	2.50		
505	AL_CC	Rock	Kas	Great Valley complex, unit A, sandstone	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
506	AL_CC	Rock	Kb	Great Valley complex, unit B, sandstone and shale	2.25		
507	AL_CC	Rock	Kb?	Great Valley complex, unit B, sandstone and shale	2.25		
508	AL_CC	Rock	Kbs	Great Valley complex, unit B, sandstone	2.00		
509	AL_CC	Rock	Kbs?	Great Valley complex, unit B, sandstone	2.00		
510	AL_CC	Rock	Kbsh	Great Valley complex, unit B, shale	2.50		
511	AL_CC	Rock	Kbsh?	Great Valley complex, unit B, shale	2.50		
512	AL_CC	Rock	Kc	Great Valley complex, conglomerate	2.00		
513	AL_CC	Rock	Kcl	Great Valley complex, unit C, lower, shale	2.50		
514	AL_CC	Rock	Kcls	Great Valley complex, unit C, lower, sandstone	2.00		
515	AL_CC	Rock	Kcm	Great Valley complex, unit C, middle, sandstone	2.00		
516	AL_CC	Rock	Kcs	Great Valley complex, quartz arenite	2.00		
517	AL_CC	Rock	Kcu	Great Valley complex, unit C, upper, shale	2.50		
518	AL_CC	Rock	Kcu?	Great Valley complex, unit C, upper, shale	2.50		
519	AL_CC	Rock	Kcus	Great Valley complex, unit C, upper, sandstone	2.00		
520	AL_CC	Rock	Kcv	Great Valley complex, ss and cg of Castro Valley	2.00		
521	AL_CC	Rock	Kd	Great Valley complex, unit D, sandstone	2.00		
522	AL_CC	Rock	Kd?	Great Valley complex, unit D, sandstone	2.00		
523	AL_CC	Rock	Kds	Great Valley complex, unit D, shale?	2.50		
524	AL_CC	Rock	Kdv	Great Valley complex, Deer Valley Sandstone	2.00		
525	AL_CC	Rock	Kel	Great Valley complex, unit E, lower, siltstone	2.50		
526	AL_CC	Rock	Kel?	Great Valley complex, unit E, lower, siltstone?	2.50		
527	AL_CC	Rock	Kels	Great Valley complex, unit E, lower, sandstone	2.00		
528	AL_CC	Rock	Keu	Great Valley complex, unit E, upper,	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				siltstone			
529	AL_CC	Rock	Kkh	Great Valley complex, Horsetown Formation	2.00		
530	AL_CC	Rock	Ko	Great Valley complex, Oakland Conglomerate	2.00		
531	AL_CC	Rock	Kp	Great Valley complex, Pinehurst Shale	2.50		
532	AL_CC	Rock	Kr	Great Valley complex, Redwood Canyon Formation	2.00		
533	AL_CC	Rock	Ks	Great Valley complex, sandstone and shale	2.25		
534	AL_CC	Rock	Ksh?	Great Valley complex, shale	2.50		
535	AL_CC	Rock	Kslt	Great Valley complex, Oakland Conglomerate, siltstone	2.25		
536	AL_CC	Rock	Kss	Great Valley complex, lithic sandstone	2.00		
537	AL_CC	Rock	Ksu	Great Valley complex, sandstone and shale	2.25		
538	AL_CC	Rock	Ksuh	Great Valley complex, shale	2.50		
539	AL_CC	Rock	Ksus	Great Valley complex, sandstone and shale	2.25		
540	AL_CC	Rock	Ku	Great Valley complex, sandstone and shale, Undivided	2.25		
541	AL_CC	Rock	Ku?	Great Valley complex	2.00		
542	AL_CC	Rock	Kus	Great Valley complex, sandstone	2.00		
543	PA100	Rock	Ka	Great Valley complex?, conglomerate of Anchor Bay	2.00		
543	PA100	Rock	Ka	Great Valley complex?, conglomerate of Anchor Bay	2.00		
543	PA100	Rock	Ka	Great Valley complex?, conglomerate of Anchor Bay	2.00		
544	PA100	Rock	Kpp	Great Valley complex, Nacimiento Block, Pigeon Point Formation	2.00		
544	PA100	Rock	Kpp	Great Valley complex, Nacimiento Block, Pigeon Point Formation	2.00		
544	PA100	Rock	Kpp	Great Valley complex, Nacimiento Block, Pigeon Point Formation	2.00		
545	PA100	Rock	Ks	unnamed sandstone and shale, Cretaceous?, Highway 92	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
545	PA100	Rock	Ks	unnamed sandstone and shale, Cretaceous?, Highway 92	2.50		
545	PA100	Rock	Ks	unnamed sandstone and shale, Cretaceous?, Highway 92	2.50		
546	PA100	Rock	Ksh	unnamed shale, Late Cretaceous, San Francisquito Creek	2.75		
546	PA100	Rock	Ksh	unnamed shale, Late Cretaceous, San Francisquito Creek	2.75		
546	PA100	Rock	Ksh	unnamed shale, Late Cretaceous, San Francisquito Creek	2.75		
547	SJ100	Rock	Kau	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
547	SJ100	Rock	Kau	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
547	SJ100	Rock	Kau	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
548	SJ100	Rock	Kcu	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
548	SJ100	Rock	Kcu	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
548	SJ100	Rock	Kcu	Great Valley complex, sandstone, mudstone, and conglomerate, Late	2.00		
549	SSC	Rock	Kcg	conglomerate, Cretaceous?, Sargent Fault Zone	2.00		
549	SSC	Rock	Kcg	conglomerate, Cretaceous?, Sargent Fault Zone	2.00		
549	SSC	Rock	Kcg	conglomerate, Cretaceous?, Sargent Fault Zone	2.00		
550	SSC	Rock	Kcu	Great Valley complex, sandstone, mudstone, conglomerate, Coyote Re	2.00		
550	SSC	Rock	Kcu	Great Valley complex, sandstone, mudstone, conglomerate, Coyote Re	2.00		
550	SSC	Rock	Kcu	Great Valley complex, sandstone, mudstone, conglomerate, Coyote Re	2.00		
551	OAK	Rock	Kc	Great Valley complex, conglomerate	2.00		
552	OAK	Rock	Kcg		2.00		
553	OAK	Rock	Kcs	Great Valley complex, quartz arenite	2.00		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
554	OAK	Rock	Kcv	Great Valley complex, ss and cg of Castro Valley	2.00		
555	OAK	Rock	Kjm	Great Valley complex, Joaquin Miller Formation	2.00		
556	OAK	Rock	Ko	Great Valley complex, Oakland Conglomerate	2.00		
557	OAK	Rock	Kp	Great Valley complex, Pinehurst Shale	2.50		
558	OAK	Rock	Kr	Great Valley complex, Redwood Canyon Formation	2.00		
559	OAK	Rock	Ksc	Great Valley complex, Shephard Creek Formation	2.00		
560	OAK	Rock	Ksh	Great Valley complex, shale	2.50		
561	OAK	Rock	Kslt	Great Valley complex, Oakland Conglomerate, siltstone	2.00		
562	OAK	Rock	Kss	Great Valley complex, lithic sandstone Unnamed sandstone in the Oa	2.50	Cretaceous	Cretaceous
563	OAK	Rock	Ku	Great Valley complex, sandstone and shale, Undivided	2.50		
564	OAK	Rock	Kus	Great Valley complex, Sandstone, siltstone, and shale	2.50	Cretaceous	Cretaceous
565	LOMA	Rock	Kuc	Great Valley Sequence Conglomerate (Upper Cretaceous)	2.00	Upper Cretaceous	Upper Cretaceous
566	LOMA	Rock	Kuc?	Great Valley Sequence Conglomerate (Upper Cretaceous)	2.00	Upper Cretaceous	Upper Cretaceous
567	LOMA	Rock	kus	Great Valley complex, ss and shale Loma Prieta	2.25		
568	LOMA	Rock	Kus?	Sandstone and shale (Upper Cretaceous)	2.75	Upper Cretaceous	Upper Cretaceous
569	MO100	Rock	Kp	Great Valley complex, Panoche Formation	4.00		
570	MO100	Rock	Kp?	Great Valley complex, Panoche Formation	4.00		
571	MO100	Rock	Kpc	Great Valley complex, Panoche Formation, conglomerate	2.00		
572	MO100	Rock	Kps	Great Valley complex, Panoche Formation, sandstone	2.00		
573	MO100	Rock	Ku	Great Valley complex, upper sedimentary rocks	2.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
574	MO100	Rock	Ku?	Great Valley complex, upper sedimentary rocks?	2.00		
575	PE_GEO10	Rock	Kn	Great Valley Sequence, Novato Conglomerate. Massive, well-cemented	2.00		
575	PE_GEO10	Rock	Kn	Great Valley Sequence, Novato Conglomerate. Massive, well-cemented	2.00		
575	PE_GEO10	Rock	Kn	Great Valley Sequence, Novato Conglomerate. Massive, well-cemented	2.00		
576	NOVA_GEO9	Rock	Kn	Great Valley Sequence, Novato Conglomerate. Massive, well-cemented	2.00		
577	CORD_GEO8	Rock	Kgv	Great Valley Sequence (Cretaceous). Sandstone, siltstone, shale, a	2.00		
578	CORD_GEO8	Rock	Klgv	Great Valley Sequence, undivided (Jurassic-Cretaceous). Sandstone,	2.00		
579		Rock	Kgvu	Great Valley complex, sandstone, shale, conglomerate, Late Cretace	2.00		
580	PA100	Rock	Tls	Lambert Shale and San Lorenzo Formation, undivided	3.50		
580	PA100	Rock	Tls	Lambert Shale and San Lorenzo Formation, undivided	3.50		
580	PA100	Rock	Tls	Lambert Shale and San Lorenzo Formation, undivided	3.50		
581	NESF	Rock	Tsr	San Ramon Sandstone	2.50		
582	PA100	Rock	Tla	Lambert Shale	3.50		
582	PA100	Rock	Tla	Lambert Shale	3.50		
582	PA100	Rock	Tla	Lambert Shale	3.50		
583	PA100	Rock	Tuv	unnamed sedimentary and volcanic rocks, Miocene and Oligocene, Pig	1.50		
583	PA100	Rock	Tuv	unnamed sedimentary and volcanic rocks, Miocene and Oligocene, Pig	1.50		
583	PA100	Rock	Tuv	unnamed sedimentary and volcanic rocks, Miocene and Oligocene, Pig	1.50		
584	PA100	Rock	Tvq	Vaqueros Formation	2.50		
584	PA100	Rock	Tvq	Vaqueros Formation	2.50		
584	PA100	Rock	Tvq	Vaqueros Formation	2.50		
585	SSC	Rock	Tps	siliceous shale and sandstone of Mount Pajaro area	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
585	SSC	Rock	Tps	siliceous shale and sandstone of Mount Pajaro area	2.50		
585	SSC	Rock	Tps	siliceous shale and sandstone of Mount Pajaro area	2.50		
586	SC	Rock	Tmp	shale of Mount Pajaro area	2.75		
586	SC	Rock	Tmp	shale of Mount Pajaro area	2.75		
586	SC	Rock	Tmp	shale of Mount Pajaro area	2.75		
587	LOMA	Rock	Tla	Lambert Shale (lower Miocene)	3.50	lower Miocene	lower Miocene
588	LOMA	Rock	Tme	Shale and sandstone of Highland Way (lower Miocene to lower Eocene	2.50	lower Miocene	lower Eocene
589	LOMA	Rock	Tt	Temblor Sandstone (middle Miocene to Oligocene?)	2.50	middle Miocene	Oligocene?
590	LOMA	Rock	Tt?	Temblor Sandstone (middle Miocene to Oligocene?)	2.50	middle Miocene	Oligocene?
591	LOMA	Rock	Tv	Vaqueros Formation (lower Miocene and Oligocene)	2.50	lower Miocene	Oligocene
592	LOMA	Rock	Tv?	Vaqueros Formation (lower Miocene and Oligocene)	2.50	lower Miocene	Oligocene
593		Rock	Tts	Tuffaceous sandstone, Miocene and(or) Oligocene, Sobrante Ridge (c	2.00		
594	SM	Rock	Tmb	Mindego Basalt	1.50		
594	SM	Rock	Tmb	Mindego Basalt	1.50		
594	SM	Rock	Tmb	Mindego Basalt	1.50		
595	PA100	Rock	Tmb	Mindego Basalt	1.50		
595	PA100	Rock	Tmb	Mindego Basalt	1.50		
595	PA100	Rock	Tmb	Mindego Basalt	1.50		
596	NESF	Rock	Tbh	Briones Sandstone, Hercules Shale member	3.50		
597	NESF	Rock	Tbl	Briones Sandstone, lower member	2.50		
598	NESF	Rock	Tbr	Briones Sandstone, undivided	2.50		
599	NESF	Rock	Tbu	Briones Sandstone, upper member	2.50		
600	NESF	Rock	Tc	Cierbo Sandstone	2.50		
601	NESF	Rock	Tcc	Claremont Shale	3.50		
602	NESF	Rock	Tcgl	Conglomerate, late Miocene, El Sobrante	3.50		
603	NESF	Rock	Tdi	diatomite, Miocene, El Sobrante	1.00		
604	NESF	Rock	Th	Hambre Sandstone	3.00		
605	NESF	Rock	Tn	Neroly Sandstone	2.75		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
606	NESF	Rock	Tn?	Neroly Sandstone?	2.75		
607	NESF	Rock	Tor	Orinda Formation	4.00		
608	NESF	Rock	Tr	Rodeo Shale	3.50		
609	NESF	Rock	Ts	Sobrante Sandstone	2.50		
610	NESF	Rock	Tsa	Sandstone, middle Miocene, El Sobrante	2.50		
611	NESF	Rock	Tt	Tice Shale	3.50		
612	NESF	Rock	Tut	tuffaceous sandstone, late Miocene, Hercules	2.00		
613	ESWN	Rock	Tms	sandstone, middle Miocene, Carneros Valley	2.50		
614	ESWN	Rock	Tn	Neroly Sandstone	2.75		
615	WSO	Rock	Tsm	Sandstone and mudstone of Fort Ross	2.50		
616	MA	Rock	Tm	Monterey shale	3.50		
617	MA	Rock	Ts	Unnamed sandstone/Sandstone, Miocene, Burdell Mountain	2.50		
618	MA	Rock	Tsc	Santa Cruz Mudstone	3.50	late Miocene	late Miocene
619	PR	Rock	Tl	Laird Sandstone (middle Miocene)	2.50		
619	PR	Rock	Tl	Laird Sandstone (middle Miocene)	2.50		
619	PR	Rock	Tl	Laird Sandstone (middle Miocene)	2.50		
620	PR	Rock	Tm	Monterey Formation (middle to uper Miocene)	3.50		
620	PR	Rock	Tm	Monterey Formation (middle to uper Miocene)	3.50		
620	PR	Rock	Tm	Monterey Formation (middle to uper Miocene)	3.50		
621	PR	Rock	Tsc	Santa Cruz Mudstone (upper Miocene)	3.50	late Miocene	late Miocene
621	PR	Rock	Tsc	Santa Cruz Mudstone (upper Miocene)	3.50	late Miocene	late Miocene
621	PR	Rock	Tsc	Santa Cruz Mudstone (upper Miocene)	3.50	late Miocene	late Miocene
622	PR	Rock	Tsm	Santa Margarita Sandstone (upper Miocene)	3.00		
622	PR	Rock	Tsm	Santa Margarita Sandstone (upper Miocene)	3.00		
622	PR	Rock	Tsm	Santa Margarita Sandstone (upper Miocene)	3.00		
623	AL_CC	Rock	Tbd	Briones Formation, D member	2.50		
624	AL_CC	Rock	Tbe	Briones Formation, E member	3.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
625	AL_CC	Rock	Tbg	Briones Formation, G member	3.00		
626	AL_CC	Rock	Tbi	Briones Formation, I member	2.75		
627	AL_CC	Rock	Tbr	Briones Formation, undivided	2.50		
628	AL_CC	Rock	Tbr?	Briones Formation, undivided	2.50		
629	AL_CC	Rock	Tc	Cierbo Sandstone	2.50		
630	AL_CC	Rock	Tccs	Claremont Chert, sandstone interbeds	2.50		
631	AL_CC	Rock	Tcs	Claremont Chert, shale and chert	2.50		
632	AL_CC	Rock	Tcsc	Cierbo Sandstone, sandstone and conglomerate	2.50		
633	AL_CC	Rock	Tcsc?	Cierbo Sandstone?, sandstone and conglomerate	2.50		
634	AL_CC	Rock	Th	Hambre Sandstone	3.00		
635	AL_CC	Rock	Tn	Neroly Sandstone	3.00		
636	AL_CC	Rock	Tn?	Neroly Sandstone?	3.00		
637	AL_CC	Rock	Tnc	Neroly Sandstone, conglomerate	2.50		
638	AL_CC	Rock	Tns	Neroly Sandstone, siltstone beds	3.25		
639	AL_CC	Rock	To	Oursan Sandstone	2.50	Miocene	Miocene
640	AL_CC	Rock	To?	Oursan Sandstone	2.50		
641	AL_CC	Rock	Tor	Orinda Formation	4.00		
642	AL_CC	Rock	Tr	Rodeo Shale	3.50		
643	AL_CC	Rock	Tro	Rodeo, Hambre, Tice, and Oursan, undivided	3.50		
644	AL_CC	Rock	Ts	Sobrante Sandstone	2.50		
645	AL_CC	Rock	Tt	Tice Shale	3.50		
646	AL_CC	Rock	Tt?	Tice Shale?	3.50		
647	AL_CC	Rock	Ttem	Temblor Sandstone	2.50		
648	AL_CC	Rock	Tush	gray shale, Miocene, Oakland Hills	2.75		
649	PA100	Rock	Tlad	Ladera Sandstone	2.50		
649	PA100	Rock	Tlad	Ladera Sandstone	2.50		
649	PA100	Rock	Tlad	Ladera Sandstone	2.50		
650	PA100	Rock	Tlo	Lompico Sandstone	2.50		
650	PA100	Rock	Tlo	Lompico Sandstone	2.50		
650	PA100	Rock	Tlo	Lompico Sandstone	2.50		
651	PA100	Rock	Tm	Monterey Formation	3.50		
651	PA100	Rock	Tm	Monterey Formation	3.50		
651	PA100	Rock	Tm	Monterey Formation	3.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
652	PA100	Rock	Tms	unnamed marine sandstone and shale, late Miocene, Los Altos	2.50		
652	PA100	Rock	Tms	unnamed marine sandstone and shale, late Miocene, Los Altos	2.50		
652	PA100	Rock	Tms	unnamed marine sandstone and shale, late Miocene, Los Altos	2.50		
653	PA100	Rock	Tsc	Santa Cruz Mudstone	3.50	late Miocene	late Miocene
653	PA100	Rock	Tsc	Santa Cruz Mudstone	3.50	late Miocene	late Miocene
653	PA100	Rock	Tsc	Santa Cruz Mudstone	3.50	late Miocene	late Miocene
654	PA100	Rock	Tsm	Santa Margarita Sandstone	3.00		
654	PA100	Rock	Tsm	Santa Margarita Sandstone	3.00		
654	PA100	Rock	Tsm	Santa Margarita Sandstone	3.00		
655	SJ100	Rock	Tbr	Briones Sandstone	2.50		
655	SJ100	Rock	Tbr	Briones Sandstone	2.50		
655	SJ100	Rock	Tbr	Briones Sandstone	2.50		
656	SJ100	Rock	Tcc	Claremont Formation	3.50		
656	SJ100	Rock	Tcc	Claremont Formation	3.50		
656	SJ100	Rock	Tcc	Claremont Formation	3.50		
657	SJ100	Rock	Tlt	sls and ss (m and upper Mioc), Mt Hamilton area	3.00	upper Miocene	Middle Miocene
657	SJ100	Rock	Tlt	sls and ss (m and upper Mioc), Mt Hamilton area	3.00	upper Miocene	Middle Miocene
657	SJ100	Rock	Tlt	sls and ss (m and upper Mioc), Mt Hamilton area	3.00	upper Miocene	Middle Miocene
658	SJ100	Rock	Tlt?	sls and ss (m and upper Mioc), Mt Hamilton area?	3.00	upper Miocene	Middle Miocene
658	SJ100	Rock	Tlt?	sls and ss (m and upper Mioc), Mt Hamilton area?	3.00	upper Miocene	Middle Miocene
658	SJ100	Rock	Tlt?	sls and ss (m and upper Mioc), Mt Hamilton area?	3.00	upper Miocene	Middle Miocene
659	SJ100	Rock	Tor	Orinda Formation	4.00		
659	SJ100	Rock	Tor	Orinda Formation	4.00		
659	SJ100	Rock	Tor	Orinda Formation	4.00		
660	SJ100	Rock	Tso	Sandstone of Silver Creek, Miocene	2.50		
660	SJ100	Rock	Tso	Sandstone of Silver Creek, Miocene	2.50		
660	SJ100	Rock	Tso	Sandstone of Silver Creek, Miocene	2.50		
661	SJ100	Rock	Tts	Temblor Sandstone	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
661	SJ100	Rock	Tts	Temblor Sandstone	2.50		
661	SJ100	Rock	Tts	Temblor Sandstone	2.50		
662	SSC	Rock	Tms	Monterey Formation	3.50		
662	SSC	Rock	Tms	Monterey Formation	3.50		
662	SSC	Rock	Tms	Monterey Formation+K1865	3.50		
663	SSC	Rock	Tus	unnamed sandstone and conglomerate, Miocene, Sargent Fault Zone	1.50		
663	SSC	Rock	Tus	unnamed sandstone and conglomerate, Miocene, Sargent Fault Zone	1.50		
663	SSC	Rock	Tus	unnamed sandstone and conglomerate, Miocene, Sargent Fault Zone	1.50		
664	SC	Rock	Tm	Monterey Forrmation	3.50		
664	SC	Rock	Tm	Monterey Forrmation	3.50		
664	SC	Rock	Tm	Monterey Forrmation	3.50		
665	SC	Rock	Tsm	Santa Margarita Sandstone	3.00		
665	SC	Rock	Tsm	Santa Margarita Sandstone	3.00		
665	SC	Rock	Tsm	Santa Margarita Sandstone	3.00		
666	OAK	Rock	Tbd	Briones Formation, D member	2.50		
667	OAK	Rock	Tbe	Briones Formation, E member	3.50		
668	OAK	Rock	Tbf	Briones Formation, F member	3.00		
669	OAK	Rock	Tbg	Briones Formation, G member	3.00		
670	OAK	Rock	Tbgl	Briones Formation, G member, conglomerate	2.50		
671	OAK	Rock	Tbgl	Briones Formation, G member, limestone	2.50		
672	OAK	Rock	Tbh	Briones Formation, Hercules Shale member	3.50		
673	OAK	Rock	Tbi	Briones Formation, I member	2.75		
674	OAK	Rock	Tbl	Briones Formation, lower member	2.50		
675	OAK	Rock	Tbr	Briones Formation	2.50		
676	OAK	Rock	Tbu	Briones Formation, upper member	2.50		
677	OAK	Rock	Tc	Cierbo Sandstone	2.50		
678	OAK	Rock	Tcc	Claremont Chert	2.50		
679	OAK	Rock	Tccs	Claremont Shale, sandstone and siltstone beds	2.50		
680	OAK	Rock	Tccs?	Claremont Shale, sandstone and siltstone beds, identification unce	2.50		
681	OAK	Rock	Tchs	Unnamed shale, Miocene, Castle Hill	2.75		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
682	OAK	Rock	Tcs	Claremont Shale	3.50		
683	OAK	Rock	Tdi	Diatomite	1.00	Miocene	Miocene
684	OAK	Rock	Th	Hambre Sandstone	3.00		
685	OAK	Rock	Th?	Hambre Sandstone, identification uncertain	3.00		
686	OAK	Rock	Tms	Moraga volcanics, sedimentary interbeds	1.50		
687	OAK	Rock	Tmu	mudstone, Miocene	2.75		
688	OAK	Rock	Tn	Neroly Sandstone	3.00		
689	OAK	Rock	Tn?	Neroly? Sandstone	3.00		
690	OAK	Rock	To	Oursan Sandstone	2.50		
691	OAK	Rock	To?	Oursan? Sandstone	2.50		
692	OAK	Rock	Tor	Orinda Formation	4.00		
693	OAK	Rock	Tr	Rodeo Shale	3.50		
694	OAK	Rock	Tr?	Rodeo? shale	3.50		
695	OAK	Rock	Tro	Rodeo, Hambre, Tice, and Oursan, undivided	3.50		
696	OAK	Rock	Ts	Sobrante Sandstone	2.50		
697	OAK	Rock	Ts?	Sobrante? Sandstone	2.50		
698	OAK	Rock	Tsa	sandstone, Miocene	2.50		
699	OAK	Rock	Tst	Siesta Formation	4.50		
700	OAK	Rock	Tt	Tice Shale	3.50		
701	OAK	Rock	Tt?	Tice? Shale	3.50		
702	OAK	Rock	Tuc	conglomerate, Miocene	2.00		
703	OAK	Rock	Tush	gray shale, Miocene	2.75		
704	LOMA	Rock	Tlo	Lompico Sandstone (middle and lower Miocene)	2.50	middle	lower Miocene
705	LOMA	Rock	Tm	Monterey Formation (middle Miocene)	3.50	middle Miocene	middle Miocene
706	LOMA	Rock	Tms	Monterey Shale (middle and lower Miocene)	3.50	middle	lower Miocene
707	LOMA	Rock	Tsc	Santa Cruz Mudstone (upper Miocene)	3.50	late Miocene	late Miocene
708	LOMA	Rock	Tsm	Santa Margarita Sandstone (upper Miocene)	3.00	upper Miocene	upper Miocene
709	LOMA	Rock	Tsm?	Santa Margarita Sandstone (upper Miocene)	3.00	upper Miocene	upper Miocene
710	MO100	Rock	Mlt	Lone Tree Formation	3.50		
711	MO100	Rock	Mmy	Monterey Formation	3.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
712	MO100	Rock	Msh	organic mudstone, Miocene, Mt Pajaro	3.00		
713	MO100	Rock	Msm	Santa Margarita Sandstone	3.00		
714	MO100	Rock	Msm?	Santa Margarita Sandstone	3.00		
715	MO100	Rock	Msu	sedimentary rocks, Miocene, Carmel	2.50		
716	MO100	Rock	Msu?	sedimentary rocks, Miocene, Carmel	2.50		
717	MO100	Rock	Mte	Temblor Sandstone	2.50		
718	MO100	Rock	Mus	Sandstone, Miocene, Spreckles	2.50		
719	MO100	Rock	Mus?	Sandstone, Miocene, Spreckles	2.50		
720	PE_GEO10	Rock	Ts	Tuffaceous, fossiliferous sandstone underlying the volcanics of Bu	2.00	Miocene	Miocene
720	PE_GEO10	Rock	Ts	Tuffaceous, fossiliferous sandstone underlying the volcanics of Bu	2.00	Miocene	Miocene
720	PE_GEO10	Rock	Ts	Tuffaceous, fossiliferous sandstone underlying the volcanics of Bu	2.00	Miocene	Miocene
721	CORD_GEO8	Rock	Tsp	San Pablo Group	2.50	Miocene	Miocene
722	CORD_GEO8	Rock	Tsp?	San Pablo Group?	2.50	Miocene	Miocene
723	FAIR_GEO3	Rock	Tnr	Neroly Sandstone. Blue sandstone and tuffaceous sandstone with int	3.00	Miocene	Miocene
724	NESF	Rock	Tdm	Donall Ranch volcanics, mafic member	1.50		
725	NESF	Rock	Tdr	Donall Ranch volcanics, rhyolite member	1.50		
726	NESF	Rock	Tpb	Putnam Peak Basalt	1.50		
727	NESF	Rock	Tv	Cierbo Sandstone, basalt interbeds	2.50		
728	ESWN	Rock	Tb		5.00		
729	ESWN	Rock	Tbm	Burdell Mountain volcanics	2.00		
730	WSO	Rock	Twgt	Tuff in Wilson Grove Formation (Roblar Tuff)	4.50	Miocene	Miocene
731	AL_CC	Rock	Tbp	Bald Peak Basalt	1.50		
732	AL_CC	Rock	Tlt	Lafayette Tuff	2.00		
733	AL_CC	Rock	Torv	Orinda Formation, volcanic interbed	3.50		
734	AL_CC	Rock	Tsv	silicic intrusive rocks, Miocene, Mt Diablo northeast	1.50		
735	PA100	Rock	Tpm	Page Mill Basalt	1.50	Miocene	Miocene
735	PA100	Rock	Tpm	Page Mill Basalt	1.50	Miocene	Miocene
735	PA100	Rock	Tpm	Page Mill Basalt	1.50	Miocene	Miocene
736	SJ100	Rock	Torv	Orinda Formation, basalt and andesite	1.50		
736	SJ100	Rock	Torv	Orinda Formation, basalt and andesite	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
736	SJ100	Rock	Torv	Orinda Formation, basalt and andesite	1.50		
737	SJ100	Rock	Tqi	Quien Sabe Volcanics, intrusive phase	1.50	upper Miocene	upper Miocene
737	SJ100	Rock	Tqi	Quien Sabe Volcanics, intrusive phase	1.50	upper Miocene	upper Miocene
737	SJ100	Rock	Tqi	Quien Sabe Volcanics, intrusive phase	1.50	upper Miocene	upper Miocene
738	SJ100	Rock	Tqs	Quien Sabe Volcanics (upper Miocene)	1.50	upper Miocene	upper Miocene
738	SJ100	Rock	Tqs	Quien Sabe Volcanics (upper Miocene)	1.50	upper Miocene	upper Miocene
738	SJ100	Rock	Tqs	Quien Sabe Volcanics (upper Miocene)	1.50	upper Miocene	upper Miocene
739	SJ100	Rock	Tv	volcanic rocks, undivided, Diablo Range	1.50		
739	SJ100	Rock	Tv	volcanic rocks, undivided, Diablo Range	1.50		
739	SJ100	Rock	Tv	volcanic rocks, undivided, Diablo Range	1.50		
740	SJ100	Rock	Tvo	andesite of Silver Creek (Miocene)	1.50		
740	SJ100	Rock	Tvo	andesite of Silver Creek (Miocene)	1.50		
740	SJ100	Rock	Tvo	andesite of Silver Creek (Miocene)	1.50		
741	SSC	Rock	Tia	Quien Sabe volcanics, intrusive andesite	1.50	upper Miocene	upper Miocene
741	SSC	Rock	Tia	Quien Sabe volcanics, intrusive andesite	1.50	upper Miocene	upper Miocene
741	SSC	Rock	Tia	Quien Sabe volcanics, intrusive andesite	1.50	upper Miocene	upper Miocene
742	SSC	Rock	Tid	Quien Sabe volcanics, intrusive dacite	1.50	upper Miocene	upper Miocene
742	SSC	Rock	Tid	Quien Sabe volcanics, intrusive dacite	1.50	upper Miocene	upper Miocene
742	SSC	Rock	Tid	Quien Sabe volcanics, intrusive dacite	1.50	upper Miocene	upper Miocene
743	SSC	Rock	Tud	Quien Sabe volcanics, dacite	1.50	upper Miocene	upper Miocene
743	SSC	Rock	Tud	Quien Sabe volcanics, dacite	1.50	upper Miocene	upper Miocene
743	SSC	Rock	Tud	Quien Sabe volcanics, dacite	1.50	upper Miocene	upper Miocene
744	SSC	Rock	Tva	Quien Sabe volcanics, extrusive andesite	1.50	upper Miocene	upper Miocene
744	SSC	Rock	Tva	Quien Sabe volcanics, extrusive andesite	1.50	upper Miocene	upper Miocene
744	SSC	Rock	Tva	Quien Sabe volcanics, extrusive andesite	1.50	upper Miocene	upper Miocene
745	SSC	Rock	Tvb	Quien Sabe volcanics, extrusive basalt	1.50	upper Miocene	upper Miocene
745	SSC	Rock	Tvb	Quien Sabe volcanics, extrusive basalt	1.50	upper Miocene	upper Miocene
745	SSC	Rock	Tvb	Quien Sabe volcanics, extrusive basalt	1.50	upper Miocene	upper Miocene
746	OAK	Rock	Tbp	Bald Peak Basalt	1.50		
747	OAK	Rock	Tlt	Lafayette Tuff	2.00		
748	OAK	Rock	Tmb	Moraga Formation	4.00		
749	LOMA	Rock	Ttv	Volcanic and intrusive rocks (middle Miocene)	1.50	middle Miocene	middle Miocene
750	LOMA	Rock	Tus	Unnamed sandstone (middle Miocene or younger)	2.50	younger	middle Miocene

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
751	LOMA	Rock	Tus?	Unnamed sandstone (middle Miocene or younger)	2.50	younger	middle Miocene
752	MO100	Rock	Miqa	Quien Sabe Volcanics, intrusive andesite	1.50	upper Miocene	upper Miocene
753	MO100	Rock	Miqb	Quien Sabe Volcanics, intrusive basalt	1.50	upper Miocene	upper Miocene
754	MO100	Rock	Miqd	Quien Sabe Volcanics, intrusive dacite	1.50	upper Miocene	upper Miocene
755	MO100	Rock	Miqr	Quien Sabe Volcanics, intrusive rhyolite	1.50	upper Miocene	upper Miocene
756	MO100	Rock	Mv	unamed volcanics, Miocene, locally interbedded in Temblor Sandston	2.50		
757	MO100	Rock	Mva	unnamed volcanics, Miocene, andesite member	1.50		
758	MO100	Rock	Mvq	Quien Sabe Volcanics	1.50	upper Miocene	upper Miocene
759	MO100	Rock	Mvqa	Quien Sabe Volcanics, andesite flows and breccia	1.50	upper Miocene	upper Miocene
760	MO100	Rock	Mvqb	Quien Sabe Volcanics, basalt flows and breccia	1.50	upper Miocene	upper Miocene
761	MO100	Rock	Mvqd	Quien Sabe Volcanics, dacite flows	1.50	upper Miocene	upper Miocene
762	MO100	Rock	Mvqr	Quien Sabe Volcanics, rhyolite flows	1.50	upper Miocene	upper Miocene
763	MO100	Rock	Tv	volcanic rocks, Miocene, San Juan Bautista	1.50		
764	TR_GEO4	Rock	Trt	Roblar Tuff	2.00		
765	TR_GEO4	Rock	Ttvr	Donnell Ranch Volcanics of Youngman (1989),Rhyolite to dacite flow	1.50		
766	PE_GEO10	Rock	Ttvm?	Donnell Ranch Volcanics-Mafic volcanics including mafic flows and	1.50		
766	PE_GEO10	Rock	Ttvm?	Donnell Ranch Volcanics-Mafic volcanics including mafic flows and	1.50		
766	PE_GEO10	Rock	Ttvm?	Donnell Ranch Volcanics-Mafic volcanics including mafic flows and	1.50		
767	PE_GEO10	Rock	Tvbm	Volcanic rocks of Burdell Mountain. Andesite, basalt, rhyolite, a	1.50		
767	PE_GEO10	Rock	Tvbm	Volcanic rocks of Burdell Mountain. Andesite, basalt, rhyolite, a	1.50		
767	PE_GEO10	Rock	Tvbm	Volcanic rocks of Burdell Mountain. Andesite, basalt, rhyolite, a	1.50		
768	PE_GEO10	Rock	Tvbm?	Volcanic rocks of Burdell Mountain? Andesite, basalt, rhyolite, a	1.50		
768	PE_GEO10	Rock	Tvbm?	Volcanic rocks of Burdell Mountain?	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				Andesite, basalt, rhyolite, a			
768	PE_GEO10	Rock	Tvbm?	Volcanic rocks of Burdell Mountain? Andesite, basalt, rhyolite, a	1.50		
769	NOVA_GEO9	Rock	Tbv	Volcanic rocks of Burdell Mountain. Andesite, basalt, rhyolite, an	1.50	Miocene	Miocene
770	NOVA_GEO9	Rock	Tbv?	Volcanic rocks of Burdell Mountain?. Andesite, basalt, rhyolite, a	1.50	Miocene	Miocene
771	PR	Rock	m	metamorphic rocks	1.00		
771	PR	Rock	m	metamorphic rocks	1.00		
771	PR	Rock	m	metamorphic rocks	1.00		
772	SM	Rock	m	Salinian complex, marble and hornfels, Paleozoic?	1.00		
772	SM	Rock	m	Salinian complex, marble and hornfels, Paleozoic?	1.00		
772	SM	Rock	m	Salinian complex, marble and hornfels, Paleozoic?	1.00		
773	PA100	Rock	gd	Salinian complex, gneissic granodiorite	1.00		
773	PA100	Rock	gd	Salinian complex, gneissic granodiorite	1.00		
773	PA100	Rock	gd	Salinian complex, gneissic granodiorite	1.00		
774	PA100	Rock	m	Salinian complex, marble, Mesozoic or Paleozoic	1.00		
774	PA100	Rock	m	Salinian complex, marble, Mesozoic or Paleozoic	1.00		
774	PA100	Rock	m	Salinian complex, marble, Mesozoic or Paleozoic	1.00		
775	PA100	Rock	sch	metasedimentary rocks, Mesozoic or Paleozoic, Ben Lomond Mountain	1.50		
775	PA100	Rock	sch	metasedimentary rocks, Mesozoic or Paleozoic, Ben Lomond Mountain	1.50		
775	PA100	Rock	sch	metasedimentary rocks, Mesozoic or Paleozoic, Ben Lomond Mountain	1.50		
776	LOMA	Rock	Jsl	Slate of Loma Prieta Peak (Jurassic?)	2.75	Jurassic?	Jurassic?
777	MO100	Rock	msc	Schist of Sierra de Salinas	2.50		
778	MO100	Rock	Pzls	Salinian complex, Paleozoic marble	1.00		
779	MO100	Rock	PzMz	Salinian complex, metamorphic rocks	1.00		
780	PA100	Rock	Tsl	San Lorenzo Formation	3.50		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
780	PA100	Rock	Tsl	San Lorenzo Formation	3.50		
780	PA100	Rock	Tsl	San Lorenzo Formation	3.50		
781	PA100	Rock	Tsr	San Lorenzo Formation, Rices Mudstone Member	3.50		
781	PA100	Rock	Tsr	San Lorenzo Formation, Rices Mudstone Member	3.50		
781	PA100	Rock	Tsr	San Lorenzo Formation, Rices Mudstone Member	3.50		
782	OAK	Rock	Tsm	Unnamed glauconitic mudstone	2.75	Miocene	Oligocene?
783	OAK	Rock	Tsms	Interbedded sandstone	2.50	Miocene	Oligocene?
784	LOMA	Rock	Tsr	Rices Mudstone Member, San Lorenzo Formation	3.50	Oligocene	late Eocene
785	LOMA	Rock	Tsr?	Rices Mudstone Member, San Lorenzo Formation	3.50	Oligocene	late Eocene
786	MO100	Rock	EOsj	San Juan Bautista Formation	2.50	Eocene	Eocene
787	ESWN	Rock	Tkt	Kirker Tuff	1.50		
788	AL_CC	Rock	Tks	Kirker Tuff, sandstone beds	2.50		
789	AL_CC	Rock	Tsr	San Ramon Formation	2.50		
790	PA100	Rock	Tz	Zayante Sandstone	2.50		
790	PA100	Rock	Tz	Zayante Sandstone	2.50		
790	PA100	Rock	Tz	Zayante Sandstone	2.50		
791	OAK	Rock	Tsr	San Ramon Sandstone	2.50		
792	LOMA	Rock	Tz	Zayante Sandstone (lower Miocene and Oligocene)	2.50	lower Miocene	Oligocene
793	MO100	Rock	Orb	red beds, Oligocene, San Juan Bautista	2.50		
794	MO100	Rock	Orb?	red beds, Oligocene, San Juan Bautista	2.50		
795	MO100	Rock	Ovq	Vaqueros Sandstone	2.50		
796	MO100	Rock	Ovq?	Vaqueros Sandstone	2.50		
797	AL_CC	Rock	Tkt	Kirker Tuff	1.50		
798	LOMA	Rock	Tvb	Basalt flows (upper Oligocene)	1.50	upper Oligocene	upper Oligocene
799	LOMA	Rock	Tvb?	Basalt flows (upper Oligocene)	1.50	upper Oligocene	upper Oligocene
800	MO100	Rock	Opv	Pinnacles volcanics	1.50		
801	MO100	Rock	Ovc	Carmeloite of Lawson	2.50		
802	NESF	Rock	Tmz	Martinez Formation	3.25		
803	NESF	Rock	Tpu	shale and sandstone, Paleocene, Vacaville	2.50	Paleocene	Paleocene
804	NESF	Rock	Tpus	shale and sandstone, Paleocene,	2.50	Paleocene	Paleocene

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				Vacaville, basal sandstone member			
805	NESF	Rock	Tvh	Vine Hill Sandstone	2.50		
806	NESF	Rock	Tvh?	Vine Hill Sandstone	2.50		
807	NESF	Rock	Tvhl	Vine Hill Sandstone, lower member	2.50		
808	NESF	Rock	Tvhu	Vine Hill Sandstone, upper member	2.50		
809	AL_CC	Rock	Tmzl	Martinez Formation, lower member	3.25		
810	AL_CC	Rock	Tmzu	Martinez Formation, upper member	3.25		
811	AL_CC	Rock	Tps	shale and glauconitic sandstone, Paleocene, Niles	2.50	Paleocene	Paleocene
812	AL_CC	Rock	Tvh	Vine Hill Sandstone	2.50		
813	AL_CC	Rock	Tvhl	Vine Hill Sandstone, lower glauconitic sandstone	2.50		
814	AL_CC	Rock	Tvhu	Vine Hill Sandstone, upper member	2.50		
815	SM	Rock	Tss	Unnamed ss, sh, and cgl of San Pedro Point	2.50		
815	SM	Rock	Tss	Unnamed ss, sh, and cgl of San Pedro Point	2.50		
815	SM	Rock	Tss	Unnamed ss, sh, and cgl of San Pedro Point	2.50		
816	PA100	Rock	Tl	Locatelli Formation	3.50		
816	PA100	Rock	Tl	Locatelli Formation	3.50		
816	PA100	Rock	Tl	Locatelli Formation	3.50		
817	PA100	Rock	Tlss	Locatelli Formation, sandstone beds	2.50		
817	PA100	Rock	Tlss	Locatelli Formation, sandstone beds	2.50		
817	PA100	Rock	Tlss	Locatelli Formation, sandstone beds	2.50		
818	OAK	Rock	Ta	glauconitic sandstone	2.25	Paleocene	Paleocene
819	OAK	Rock	Tvh	Vine Hill Sandstone	2.50		
820	OAK	Rock	Tvhl	Vine Hill Sandstone, lower member	2.50		
821	OAK	Rock	Tvhu	Vine Hill Sandstone, upper member	2.50		
822	FAIR_GEO3	Rock	Tmz	Martinez Formation. Brown to greenish-brown sandstone with shale i	3.25	Paleocene	Paleocene
823	NESF	Rock	Tpc	Petaluma Formation, claystone member	4.00		Miocene
824	NESF	Rock	Tps	Petaluma Formation, mudrock, sandstone, and conglomerate	4.00		Miocene
825	NESF	Rock	Tps?	Petaluma Formation, mudrock, sandstone, and conglomerate	4.00		Miocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
826	NESF	Rock	Tsvs	Sonoma Volcanics, volcanic sandstone, siltstone, and conglomerate	1.50	Pliocene	Miocene
827	ESWN	Rock	Tc	Sand and gravel of Cotati	2.50		
828	ESWN	Rock	Tp	Petaluma Formation	4.00		Miocene
829	ESWN	Rock	Tss	Sonoma Volcanics, volcanic sand and gravel	1.50	Pliocene	Miocene
830	ESWN	Rock	Tssd	Sonoma Volcanics, diatomite	1.50		
831	ESWN	Rock	Twg	Wilson Grove Formation	4.50	Late Pliocene	Miocene
832	WSO	Rock	Tls	Sedimentary rocks of Little Sulphur Creek	2.50	Pliocene	Miocene
833	WSO	Rock	Tp?	Petaluma Formation	4.00		Miocene
834	WSO	Rock	Twg	Wilson Grove Formation (upper Miocene to Pliocene	4.50	Late Pliocene	
835	MA	Rock	Tpc	Petaluma Formation, gray claystone member	4.00		Miocene
836	MA	Rock	Tps	Petaluma Formation, siltstone and claystone member	4.00		Miocene
837	MA	Rock	Twg	Wilson Grove Formation	4.50	Late Pliocene	
838	PR	Rock	Tp	Purisima formation (upper Miocene to lwr Pliocene)	4.00	lower Pliocene	upper Miocene
838	PR	Rock	Tp	Purisima formation (upper Miocene to lwr Pliocene)	4.00	lower Pliocene	upper Miocene
838	PR	Rock	Tp	Purisima formation (upper Miocene to lwr Pliocene)	4.00	lower Pliocene	upper Miocene
839	AL_CC	Rock	Tgvt	Green Valley and Tassajara Formations	3.00		
840	AL_CC	Rock	Tgvt?	Green Valley and Tassajara Formations	3.00		
841	AL_CC	Rock	Tlp	fresh water limestone and mudstone, Pliocene and(or) Miocene, Suno	2.00		
842	AL_CC	Rock	Tol	Oro Loma Formation	4.50		
843	AL_CC	Rock	Tol?	Oro Loma Formation?	4.50		
844	AL_CC	Rock	Tss	sandstone, chert, limestone, Pliocene and(or) Miocene, Sunol	2.00		
845	AL_CC	Rock	Tul	limestone member (of Tus unit)	1.50		
846	AL_CC	Rock	Tus	sedimentary and volcanic rocks, Pliocene and Miocene, East Bay hil	2.00	Pliocene	Miocene
847	SM	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene
847	SM	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
847	SM	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene
848	PA100	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene
848	PA100	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene
848	PA100	Rock	Tp	Purisima Formation	4.00	Pliocene	upper Miocene
849	PA100	Rock	Tpt	Purisima Formation, Tahana Member	4.00		
849	PA100	Rock	Tpt	Purisima Formation, Tahana Member	4.00		
849	PA100	Rock	Tpt	Purisima Formation, Tahana Member	4.00		
850	SC	Rock	Tp	Purisima formation	4.00	Pliocene	upper Miocene
850	SC	Rock	Tp	Purisima formation	4.00	Pliocene	upper Miocene
850	SC	Rock	Tp	Purisima formation	4.00	Pliocene	upper Miocene
851	SC	Rock	Tps	Purisima Formation, massive sandstone	3.50		
851	SC	Rock	Tps	Purisima Formation, massive sandstone	3.50		
851	SC	Rock	Tps	Purisima Formation, massive sandstone	3.50		
852	SC	Rock	Ts	siltstone and sandstone, Pliocene and late Miocene, Pajaro Gap	2.50	Pliocene	late Miocene
852	SC	Rock	Ts	siltstone and sandstone, Pliocene and late Miocene, Pajaro Gap	2.50	Pliocene	late Miocene
852	SC	Rock	Ts	siltstone and sandstone, Pliocene and late Miocene, Pajaro Gap	2.50	Pliocene	late Miocene
853	OAK	Rock	Tcgl	Conglomerate, sandstone, siltstone	2.50	Pliocene	Pliocene
854	OAK	Rock	Tgvt	Green Valley and Tassajara Formations	3.00		
855	OAK	Rock	Tmll	Mullholland Formation, lower member	4.50		
856	OAK	Rock	Tmls	Mullholland Formation, sandstone marker beds	4.50		
857	OAK	Rock	Tmlu	Mullholland Formation, upper menber	4.50		
858	OAK	Rock	Tss	sandstone, chert, limestone,	2.00		
859	OAK	Rock	Tul	limestone member (of Tus unit)	1.50		
860	OAK	Rock	Tus	sedimentary and volcanic rocks,	2.00	Pliocene	Miocene
861	LOMA	Rock	Tp	Purisima Formation (Pliocene and upper Miocene)	4.00	Pliocene	upper Miocene
862	LOMA	Rock	Tp?	Purisima Formation (Pliocene and upper Miocene)	4.00	Pliocene	upper Miocene
863	MO100	Rock	MPe	Etchegoin Formation	3.25		
864	MO100	Rock	MPe?	Etchegoin Formation?	3.25		
865	TR_GEO4	Rock	Tco	Sand and gravel of Cotati (Miocene). A predominantly marine transi	3.50	Miocene	Miocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
866	TR_GEO4	Rock	Tpm	Middle Petaluma Fm. Siltstone with interbedded conglomerate.	3.00		
867	TR_GEO4	Rock	Twg	Wilson Grove Formation.	4.50	Miocene	Miocene
868	PE_GEO10	Rock	Tp	Petaluma Formation	4.00		Miocene
868	PE_GEO10	Rock	Tp	Petaluma Formation	4.00		Miocene
868	PE_GEO10	Rock	Tp	Petaluma Formation	4.00		Miocene
869	PE_GEO10	Rock	Tp?	Petaluma Formation?	4.00		Miocene
869	PE_GEO10	Rock	Tp?	Petaluma Formation?	4.00		Miocene
869	PE_GEO10	Rock	Tp?	Petaluma Formation?	4.00		Miocene
870	PE_GEO10	Rock	Twg	Wilson Grove Formation.	4.50	Miocene	Miocene
870	PE_GEO10	Rock	Twg	Wilson Grove Formation.	4.50	Miocene	Miocene
870	PE_GEO10	Rock	Twg	Wilson Grove Formation.	4.50	Miocene	Miocene
871	NESF	Rock	Tsv	Sonoma Volcanics	1.50		
872	NESF	Rock	Tsva	Sonoma Volcanics, andesite to basalt flows	1.50		
873	NESF	Rock	Tsva?	Sonoma Volcanics, andesite to basalt flows	1.50		
874	NESF	Rock	Tsvad	Sonoma Volcanics, andesite to dacite flows	1.50		
875	NESF	Rock	Tsvd	Sonoma Volcanics, diatomite	1.50		
876	NESF	Rock	Tsvl	Sonoma Volcanics, lithic tuff	1.50		
877	NESF	Rock	Tsvp	Sonoma Volcanics, rhyolite and perlitic flows and plugs	1.50		
878	NESF	Rock	Tsvr	Sonoma Volcanics, rhyolite flows	1.50		
879	NESF	Rock	Tsvr?	Sonoma Volcanics, rhyolite flows	1.50		
880	NESF	Rock	Tsvri	Sonoma Volcanics, rhyolite plugs and dikes	1.50		
881	NESF	Rock	Tsvt	Sonoma Volcanics, ash-flow tuff	1.50		
882	NESF	Rock	Tsvt?	Sonoma Volcanics, ash-flow tuff	1.50		
883	NESF	Rock	Tsvw	Sonoma Volcanics, welded ash-flow tuff	1.50	Pliocene	Miocene
884	ESWN	Rock	Tsa	Sonoma Volcanics, andesite to basalt	1.50		
885	ESWN	Rock	Tsag	Sonoma Volcanics, agglomerate	1.50		
886	ESWN	Rock	Tsai	Sonoma Volcanics, andesite to dacite plugs	1.50		
887	ESWN	Rock	Tsb	Sonoma Volcanics, basalt flows	1.50		
888	ESWN	Rock	Tsft	Sonoma Volcanics, tuff	1.50		
889	ESWN	Rock	Tslt	Sonoma Volcanics, lithic tuff	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
890	ESWN	Rock	Tsr	Sonoma Volcanics, rhyolite flows	1.50		
891	ESWN	Rock	Tsrb	Sonoma Volcanics, rhyolite breccia	1.50		
892	ESWN	Rock	Tsri	Sonoma Volcanics, rhyolite plugs	1.50		
893	ESWN	Rock	Tsrp	Sonoma Volcanics, perlitic rhyolite	1.50		
894	ESWN	Rock	Tsrs	Sonoma Volcanics, soda rhyolite flows	1.50		
895	ESWN	Rock	Tst	Sonoma Volcanics, ash-flow tuff	1.50		
896	ESWN	Rock	Tstx	Sonoma Volcanics, tuff?	1.50	Pliocene	Miocene
897	ESWN	Rock	Tswt	Sonoma Volcanics, welded ash-flow tuff	1.50	Pliocene	Miocene
898	WSO	Rock	Tsa	Sonoma Volcanics, andesite	1.50		
899	WSO	Rock	Tsb	Sonoma Volcanics, basalt	1.50		
900	MA	Rock	Tsa	Sonoma Volcanics, andesite to basalt lava flows	1.50		
901	MA	Rock	Tsa?	Sonoma Volcanics, andesite to basalt lava flows, identification un	1.50		
902	MA	Rock	Tsr	Sonoma Volcanics, rhyolite lava flows	1.50		
903	MA	Rock	Tsri	Sonoma Volcanics, rhyolite plugs and dikes	1.50		
904	MA	Rock	Tst	Sonoma Volcanics, pumiceous ash flow tuff	1.50		
905	MA	Rock	Tsv	Sonoma Volcanics	1.50		
906	AL_CC	Rock	Tgvtt	Green Valley and Tassajara Formations, tuff	2.75		
907	AL_CC	Rock	Tub	basalt member (of Tus unit)	1.50		
908	AL_CC	Rock	Tv	volcanic rocks, Pliocene and(or) Miocene, Niles	1.50		
909	OAK	Rock	Tcglt	Rhyolite tuff interbeds	1.50	Pliocene	Pliocene
910	OAK	Rock	Tub	basalt member (of Tus unit)	1.50		
911	MWS	Rock	Tsb	Sonoma Volcanics, Andesite, basaltic andesite and basalt	1.50	Pliocene	Miocene
912	MWS	Rock	Tsb?	Sonoma Volcanics, Andesite, basaltic andesite and basalt, identifi	1.50	Pliocene	Miocene
913	MWS	Rock	Tsbi	Sonoma Volcanics, Andesite, basaltic andesite and basalt, intrusiv	1.50	Late Pliocene	Late Pliocene
914	MWS	Rock	Tsbt	Sonoma Volcanics, Andesitic fine-grained waterlain tuff	1.50	Pliocene	Miocene
915	MWS	Rock	Tsd	Sonoma Volcanics, Dacite	1.50	Pliocene	Miocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
916	MWS	Rock	Tsr	Sonoma Volcanics, Rhyolite and rhyodacite	1.50	Pliocene	Miocene
917	MWS	Rock	Tst	Sonoma Volcanics, Rhyolite tuff	1.50	Pliocene	Miocene
918	MWS	Rock	Tst?	Sonoma Volcanics, Rhyolite tuff, identification uncertain	1.50	Pliocene	Miocene
919	MWS	Rock	Tstb	Sonoma Volcanics, Breccia	1.50	Pliocene	Miocene
920	MWS	Rock	Tstv	Sonoma Volcanics, Vitrophyre	1.50	Pliocene	Miocene
921	MWS	Rock	Tstw	Sonoma Volcanics, Welded tuff	1.50	Pliocene	Miocene
922	TR_GEO4	Rock	Tsvb	Sonoma Volcanics, Olivine basalt lava flows.	1.50		
923	CORD_GEO8	Rock	Tsb	Basalt. Black basalt flows, massive with a scoria base.	1.50	Pliocene	Pliocene
924	CORD_GEO8	Rock	Tst	Ash-flow tuff. Pumicitic, locally welded, with bedded agglomeritic	2.00	Pliocene	Pliocene
925	CORD_GEO8	Rock	Tsv	Sonoma Volcanics, undivided	1.50	Pliocene	Miocene
926	CORD_GEO8	Rock	Tsv?	Sonoma Volcanics?, undivided	1.50		
927	CORD_GEO8	Rock	Tsvt	Sonoma Volcanics, tuff, Light colored, lithic rich in places. Loc	1.50		
928	FAIR_GEO3	Rock	Tsb	Basalt. Black basalt flows, massive with a scoria base.	1.50	Pliocene	Pliocene
929	FAIR_GEO3	Rock	Tst	Ash-flow tuff. Pumicitic, locally welded, with bedded agglomeritic	2.00	Pliocene	Pliocene
930	NESF	Rock	Tpth	Tehama Formation	4.50		
931	WSO	Rock	Tor	Ohlson Ranch Formation	2.50		
932	WSO	Rock	Torc	Ohlson Ranch Formation, conglomerate	2.50		
933	WSO	Rock	Tors	Ohlson Ranch Formation, sandstone	2.50		
934	AL_CC	Rock	Tpth	Tulare Fm/Tehama Fm quad boundary	2.50		
935	AL_CC	Rock	Ttu	Tulare Formation	2.50		
936	AL_CC	Rock	Ttu?	Tulare Formation?	2.50		
937	PA100	Rock	Tpl	Purisima Formation, Lobitos Mudstone Member	4.00		
937	PA100	Rock	Tpl	Purisima Formation, Lobitos Mudstone Member	4.00		
937	PA100	Rock	Tpl	Purisima Formation, Lobitos Mudstone Member	4.00		
938	PA100	Rock	Tpp	Purisima Formation, Pomponio Mudstone Member	4.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
938	PA100	Rock	Tpp	Purisima Formation, Pomponio Mudstone Member	4.00		
938	PA100	Rock	Tpp	Purisima Formation, Pomponio Mudstone Member	4.00		
939	PA100	Rock	Tpsg	Purisima Formation, San Gregorio Sandstone Member	4.00		
939	PA100	Rock	Tpsg	Purisima Formation, San Gregorio Sandstone Member	4.00		
939	PA100	Rock	Tpsg	Purisima Formation, San Gregorio Sandstone Member	4.00		
940	PA100	Rock	Tptu	Purisima Formation, Tunitas Sandstone Member	4.00		
940	PA100	Rock	Tptu	Purisima Formation, Tunitas Sandstone Member	4.00		
940	PA100	Rock	Tptu	Purisima Formation, Tunitas Sandstone Member	4.00		
941	SJ100	Rock	Tsg	Silver Creek gravels (Pliocene)	4.50		
941	SJ100	Rock	Tsg	Silver Creek gravels (Pliocene)	4.50		
941	SJ100	Rock	Tsg	Silver Creek gravels (Pliocene)	4.50		
942	SJ100	Rock	Tsg?	Silver Creek gravels (Pliocene)?	4.50		
942	SJ100	Rock	Tsg?	Silver Creek gravels (Pliocene)?	4.50		
942	SJ100	Rock	Tsg?	Silver Creek gravels (Pliocene)?	4.50		
943	SSC	Rock	Tsc	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
943	SSC	Rock	Tsc	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
943	SSC	Rock	Tsc	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
944	SSC	Rock	Tsc?	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
944	SSC	Rock	Tsc?	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
944	SSC	Rock	Tsc?	conglomerate, sandstone, and siltstone of Sargent Hills	2.50		
945	SSC	Rock	Tscm	conglomerate, sandstone, and siltstone of Sargent Hills, marine fa	2.50		
945	SSC	Rock	Tscm	conglomerate, sandstone, and siltstone of	2.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
				Sargent Hills, marine fa			
945	SSC	Rock	Tscm	conglomerate, sandstone, and siltstone of Sargent Hills, marine fa	2.50		
946	SSC	Rock	Tscn	conglomerate, sandstone, and siltstone of Sargent Hills, nonmarine	2.50		
946	SSC	Rock	Tscn	conglomerate, sandstone, and siltstone of Sargent Hills, nonmarine	2.50		
946	SSC	Rock	Tscn	conglomerate, sandstone, and siltstone of Sargent Hills, nonmarine	2.50		
947	MO100	Rock	Ppr	Pancho Rico Formation	2.50		
948	MO100	Rock	Ppu	Purisima Formation	4.00	Pliocene	upper Miocene
949	MO100	Rock	Puc	continental mudstone, Pliocene, Lomerias Muertas	2.75		
950	MO100	Rock	Puc?	continental mudstone, Pliocene, Lomerias Muertas?	2.75		
951	MO100	Rock	Pus	continental sandstone, Pliocene, Lomerias Muertas	2.75		
952	MO100	Rock	Pus?	continental sandstone, Pliocene, Lomerias Muertas?	2.75		
953	MWS	Rock	Tgp	Fluvial and lacustrine deposits of Humbug Creek	4.00	Pliocene	Pliocene
954	MWS	Rock	Tgp?	Fluvial and lacustrine deposits of Humbug Creek, identification un	4.00	Pliocene	Pliocene
955	MWS	Rock	Tss	Sandstone	2.50	late Pliocene	Tertiary
956	CORD_GEO8	Rock	Tss	Sandstone and volcanic gravel. Poorly consolidated tan sandstone a	2.50	Pliocene	Pliocene
957	CORD_GEO8	Rock	Tss?	Sandstone and volcanic gravel?. Poorly consolidated tan sandstone	2.50	Pliocene	Pliocene
958	FAIR_GEO3	Rock	Tss	Sandstone and volcanic gravel. Poorly consolidated tan sandstone a	2.50	Pliocene	Pliocene
959	NESF	Rock	Tl	Lawlor Tuff	1.50		
960	NESF	Rock	Tpt	Pinole Tuff	1.50		
961	NESF	Rock	Tptt	Tehama Formation, Putah Tuff member	1.50		
962	AL_CC	Rock	Tb	basaltic intrusive, Pliocene, NE Mt Diablo	1.50		
963	AL_CC	Rock	Tl	Lawlor Tuff	1.50		
964	SJ100	Rock	Tba	Basalt of Anderson and Coyote Reservoirs, Pliocene	1.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
964	SJ100	Rock	Tba	Basalt of Anderson and Coyote Reservoirs, Pliocene	1.50		
964	SJ100	Rock	Tba	Basalt of Anderson and Coyote Reservoirs, Pliocene	1.50		
965	CORD_GEO8	Rock	Tsa	Andesites. Andesitic flows, breccias, and agglomerates.	1.50	Pliocene	Pliocene
966	FAIR_GEO3	Rock	Tsa	Andesites. Andesitic flows, breccias, and agglomerates.	1.50	Pliocene	Pliocene
967	NESF	Soil	Qha	alluvium, Holocene	5.00		
968	NESF	Soil	Qhaf	alluvial fan deposits, Holocene	5.00		
969	NESF	Soil	Qhb	basin deposits, Holocene	5.00		
970	NESF	Soil	Qhf	alluvial fan deposits, Holocene	5.00		
971	NESF	Soil	Qhfb	floodbasin deposits, Holocene	5.00		
972	NESF	Soil	Qhff	fine-grained alluvial fan deposits, Holocene	5.00		
973	NESF	Soil	Qhfp	floodplain deposits, Holocene	5.00		
974	NESF	Soil	Qhl	natural levee deposits, Holocene	5.00		
975	NESF	Soil	Qhl?	natural levee deposits, Holocene	5.00		
976	NESF	Soil	Qht	terrace deposits, Holocene	5.00		
977	ESWN	Soil	Qha	alluvium, Holocene	5.00		
978	ESWN	Soil	Qhb	basin deposits, Holocene	5.00		
979	ESWN	Soil	Qhf	alluvial fan deposits, Holocene	5.00		
980	ESWN	Soil	Qhff	fine-grained alluvial fan deposits, Holocene	5.00		
981	ESWN	Soil	Qht	terrace deposits, Holocene	5.00		
982	PR	Soil	Qal	alluvium, Holocene	5.00		
983	AL_CC	Soil	Qhaf	alluvial fan and fluvial deposits, Holocene	5.00		
984	AL_CC	Soil	Qhb		5.00		
985	AL_CC	Soil	Qhbs	basin deposits, salt affected, Holocene	5.00		
986	AL_CC	Soil	Qhdm		5.00		
987	AL_CC	Soil	Qhf		5.00		
988	AL_CC	Soil	Qhfp	floodplain deposits, Holocene	5.00		
989	AL_CC	Soil	Qhl	levee deposits, Holocene	5.00		
990	AL_CC	Soil	Qhsc		5.00		
991	SFS	Soil	Qal	alluvium, Holocene	5.00		
992	SFS	Soil	Qb	beach deposits, Holocene	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
993	SM	Soil	Qal	alluvium, Holocene	5.00		
994	SM	Soil	Qhaf	alluvial fan and fluvial deposits, Holocene	5.00		
995	SM	Soil	Qhb	basin deposits, Holocene	5.00		
996	SM	Soil	Qhbd	beach deposits, Holocene	5.00		
997	SM	Soil	Qhfp	flood plain deposits, Holocene	5.00		
998	SM	Soil	Qhl	natural levee deposits, Holocene	5.00		
999	SM	Soil	Qhsc	stream channel deposits, Holocene	5.00		
1000	PA100	Soil	Qal	alluvium, Holocene	5.00		
1001	PA100	Soil	Qbs	basin deposits, Holocene	5.00		
1002	PA100	Soil	Qhaf	alluvial fan and fluvial deposits, Holocene	5.00		
1003	PA100	Soil	Qhb	basin deposits, Holocene	5.00		
1004	PA100	Soil	Qhbs	basin deposits, salt-affected, Holocene	5.00		
1005	PA100	Soil	Qhfp	floodplain deposits, Holocene	5.00		
1006	PA100	Soil	Qhl	natural levee deposits, Holocene	5.00		
1007	PA100	Soil	Qhsc	stream channel deposits, Holocene	5.00		
1008	PA100	Soil	Qyf	younger, inner, alluvial fan deposits, Holocene	5.00		
1009	PA100	Soil	Qyfo	younger, outer, alluvial fan deposits, Holocene	5.00		
1010	SJ100	Soil	Qha	alluvium, Holocene	5.00		
1011	SJ100	Soil	Qhb	basin deposits, Holocene	5.00		
1012	SJ100	Soil	Qhf1	alluvial fan deposits,younger, Holocene	5.00		
1013	SJ100	Soil	Qhf2	alluvial fan deposits, older, Holocene	5.00		
1014	SJ100	Soil	Qhfp	flood plain deposits, Holocene	5.00		
1015	SJ100	Soil	Qhl	natural levee deposits, Holocene	5.00		
1016	SJ100	Soil	Qht	stream terrace deposits, Holocene	5.00		
1017	SSC	Soil	Qhaf	alluvial fan and fluvial deposits, Holocene	5.00		
1018	SSC	Soil	Qhb	basin deposits, Holocene	5.00		
1019	SSC	Soil	Qhfp	flood plain deposits, Holocene	5.00		
1020	SSC	Soil	Qhl	natural levee deposits, Holocene	5.00		
1021	SSC	Soil	Qhsc	stream channel deposits, Holocene	5.00		
1022	SC	Soil	Qb	basin deposits, Holocene	5.00	Holocene	Holocene
1023	SC	Soil	Qcf	channel fill deposits, Holocene	5.00	Holocene	Holocene
1024	SC	Soil	Qof	older flood-plain deposits, Holocene	5.00	Holocene	Holocene
1025	SC	Soil	Qyfo	alluvial fan deposits, Holocene	5.00	Holocene	Holocene
1026	OAK	Soil	Qhaf	Alluvial fan and fluvial deposits	5.00	Holocene	Holocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1027	OAK	Soil	Qhb	Basin deposits	5.00		
1028	OAK	Soil	Qhbs	Basin deposits, salt affected	5.00		
1029	OAK	Soil	Qhf		5.00		
1030	OAK	Soil	Qhfp	Floodplain deposits	5.00		
1031	OAK	Soil	Qhl	Natural levee deposits	5.00		
1032	OAK	Soil	Qhsc	Stream channel deposits	5.00		
1033	LOMA	Soil	Qhb		5.00		
1034	LOMA	Soil	Qhf	Alluvial fan deposits	5.00		
1035	LOMA	Soil	Qhfp		5.00		
1036	LOMA	Soil	Qhl		5.00		
1037	LOMA	Soil	Qof		5.00		
1038	LOMA	Soil	Qof?	identification uncertain	5.00		
1039	MO100	Soil	Qb	basin deposits, Holocene	5.00		
1040	MO100	Soil	Qd	dune sand, Holocene	5.00		
1041	MO100	Soil	Qg	stream gravel, Holocene	5.00		
1042	MWS	Soil	Qhf	Alluvial fan and fluvial terrace deposits undivided	5.00	Holocene	Holocene
1043	MWS	Soil	Qhf2	Old Holocene alluvial fan and fluvial terrace deposits	5.00	Holocene?	Holocene?
1044	MWS	Soil	Qhpf	Alluvial fan and terrace deposits	5.00	Holocene?	Pleistocene
1045	MWS	Soil	Qhpf?	Alluvial fan and terrace deposits	5.00	Holocene?	Pleistocene
1046	MWS	Soil	Qhpf1	Younger alluvial fan and terrace deposits	5.00	Holocene?	Pleistocene
1047	MWS	Soil	Qhpf2	Older alluvial fan and terrace deposits	5.00	Holocene?	Pleistocene
1048	TR_GEO4	Soil	Qha	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	modern	latest Holocene
1049	TR_GEO4	Soil	Qhf	Holocene fan deposits. Holocene alluvial fan sediments, deposited	5.00	Holocene	Holocene
1050	TR_GEO4	Soil	Qht	stream terrace deposits. Sand, gravel, silt and minor clay. Relati	5.00	Holocene	Latest Pleistocene
1051	PE_GEO10	Soil	Qha	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	modern	latest Holocene
1052	PE_GEO10	Soil	Qhf	Holocene fan deposits. Holocene alluvial fan sediments, deposited	5.00	Holocene	Holocene
1053	PE_GEO10	Soil	Qhf1	younger Holocene fan deposits.	5.00	Holocene	Holocene
1054	PE_GEO10	Soil	Qhf2	older Holocene fan deposits.	5.00	Holocene	Holocene

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1055	NOVA_GEO9	Soil	Qha	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	modern	latest Holocene
1056	NOVA_GEO9	Soil	Qhf	Holocene fan deposits. Holocene alluvial fan sediments, deposited	5.00	Holocene	Holocene
1057	NOVA_GEO9	Soil	Qht	stream terrace deposits. Sand, gravel, silt and minor clay. Relati	5.00	Holocene	Latest Pleistocene
1058	CORD_GEO8	Soil	Qha	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	modern	latest Holocene
1059	CORD_GEO8	Soil	Qhf	Holocene fan deposits. Holocene alluvial fan sediments, deposited	5.00	Holocene	Holocene
1060	FAIR_GEO3	Soil	Qha	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	modern	latest Holocene
1061	FAIR_GEO3	Soil	Qhb	basin deposits deposited in topographic lows. Sediments are more f	5.00	late Holocene	late Holocene
1062	FAIR_GEO3	Soil	Qhf	Holocene fan deposits. Holocene alluvial fan sediments, deposited	5.00	Holocene	Holocene
1063	FAIR_GEO3	Soil	Qhl	Fan levee deposits. Holocene fan sediments deposited as long, low	5.00	Holocene	Holocene
1064	NESF	Soil	Qhay	younger alluvium, late Holocene	5.00		
1065	NESF	Soil	Qhc	stream channel deposits, Holocene	5.00		
1066	ESWN	Soil	Qhay	alluvium,younger Holocene	5.00		
1067	ESWN	Soil	Qhc	stream channel deposits, Holocene	5.00		
1068	ESWN	Soil	Qhty	terrace deposits,younger Holocene	5.00		
1069	AL_CC	Soil	Qhafl	alluvial fan deposits,younger Holocene	5.00		
1070	AL_CC	Soil	Qhc		5.00		
1071	SM	Soil	Qyf	younger, inner, alluvial fan deposits, Holocene	5.00		
1072	SM	Soil	Qyfo	younger, outer, alluvial fan deposits, Holocene	5.00		
1073	PA100	Soil	Qhafl	younger alluvial fan deposits, Holocene	5.00		
1074	SJ100	Soil	Qhbm	Bay mud, late Holocene	5.00		
1075	SJ100	Soil	Qhc	stream channel deposits, Holocene	5.00		
1076	SC	Soil	Qyf	younger flood-plain deposits, Holocene	5.00	Holocene	Holocene
1077	OAK	Soil	Qhafl	Younger alluvial fan deposits	5.00		
1078	LOMA	Soil	Qhc	Stream Channel deposits	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1079	LOMA	Soil	Qhc?	Stream Channel deposits, identification uncertain	5.00		
1080	MO100	Soil	Qfl		5.00		
1081	TR_GEO4	Soil	Qhay	Alluvial deposits. Fluvial sediment deposited on the modern flood	5.00	latest Holocene	latest Holocene
1082	TR_GEO4	Soil	Qhc	stream channel deposits in active, natural stream channels. Consis	5.00	modern	Late Holocene
1083	PE_GEO10	Soil	Qhc	stream channel deposits in active, natural stream channels. Consis	5.00	modern	Late Holocene
1084	PE_GEO10	Soil	Qhty	stream terrace deposits. Stream terraces are deposited as point ba	5.00	latest Holocene	latest Holocene
1085	NOVA_GEO9	Soil	Qhc	stream channel deposits in active, natural stream channels. Consis	5.00	modern	Late Holocene
1086	CORD_GEO8	Soil	Qhc	stream channel deposits in active, natural stream channels. Consis	5.00	modern	Late Holocene
1087	FAIR_GEO3	Soil	Qhc	stream channel deposits in active, natural stream channels. Consis	5.00	modern	Late Holocene
1088	NESF	Soil	Qhbm	bay mud deposits, late Holocene	5.00		
1089	NESF	Soil	Qhdm	Delta mud deposits, late Holocene	5.00		
1090	ESWN	Soil	Qhbm	bay mud, Holocene	5.00		
1091	WSO	Soil	Qm	Bay mud, late Holocene	5.00		
1092	MA	Soil	Qm	Marine and marsh deposits	5.00	Quaternary	Quaternary
1093	AL_CC	Soil	Qhbm	bay mud, Holocene	5.00		
1094	AL_CC	Soil	Qhpm	peaty muck, Holocene	5.00	Modern	Holocene
1095	SFS	Soil	Qm	Bay mud, late Holocene	5.00		
1096	SM	Soil	Qhbm	Bay mud, late Holocene	5.00		
1097	PA100	Soil	Qhbm	bay mud deposits, late Holocene	5.00		
1098	OAK	Soil	Qhbm	Bay mud	5.00		
1099	PE_GEO10	Soil	Qhbm	bay mud. Silt, clay, peat, and fine sand deposited at or near sea	5.00	Holocene	Holocene
1100	NOVA_GEO9	Soil	Qhbm	bay mud. Silt, clay, peat, and fine sand deposited at or near sea	5.00	Holocene	Holocene
1101	CORD_GEO8	Soil	Qhbm	bay mud. Silt, clay, peat, and fine sand deposited at or near sea	5.00	Holocene	Holocene
1102	FAIR_GEO3	Soil	Qhbm	bay mud. Silt, clay, peat, and fine sand deposited at or near sea	5.00	Holocene	Holocene
1103	NESF	Soil	Qoa	alluvium, older Pleistocene	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1104	NESF	Soil	Qoa?	alluvium, older Pleistocene	5.00		
1105	NESF	Soil	Qop	pediment deposits, older Pleistocene	5.00	Early Pleistocene	Early Pleistocene
1106	ESWN	Soil	Qoa	alluvium, older Pleistocene	5.00		
1107	ESWN	Soil	Qoa?	alluvium, older Pleistocene	5.00		
1108	WSO	Soil	Qpoaf	older alluvial fan deposits, middle to early Pleistocene	5.00		
1109	WSO	Soil	Qt	alluvial and marine terrace deposits	5.00		
1110	MA	Soil	Qc	Colma Formation	5.00	Quaternary	Quaternary
1111	MA	Soil	Qmi	Millerton Formation	5.00	Quaternary	Quaternary
1112	MA	Soil	Qoal	Older alluvium	5.00	Quaternary	Quaternary
1113	MA	Soil	Qob	Older beach deposits	5.00	Quaternary	Quaternary
1114	MA	Soil	Qt	Marine and stream terrace deposits	5.00	Quaternary	Quaternary
1115	PR	Soil	Qt	terrace deposits, Pleistocene	5.00		
1116	AL_CC	Soil	Qmt	marine terrace deposits	5.00		
1117	AL_CC	Soil	Qpoaf	alluvial fan deposits, older Pleistocene	5.00		
1118	SFS	Soil	Qc	Colma Formation, early Pleistocene	5.00		
1119	SFS	Soil	Qt	marine terrace deposits, Pleistocene	5.00		
1120	SM	Soil	Qc	Colma Formation, early Pleistocene	5.00		
1121	SM	Soil	Qmt	marine terrace deposits, Pleistocene	5.00		
1122	SM	Soil	Qof	coarse-grained older alluvial fan and stream terrace deposits, Ple	5.00		
1123	PA100	Soil	Qmt	marine terrace deposits, Pleistocene	5.00		
1124	PA100	Soil	Qof	coarse-grained older alluvial fan and stream terrace deposits, Ple	5.00		
1125	PA100	Soil	Qpoaf	older alluvial fan deposits, Pleistocene	5.00		
1126	SJ100	Soil	Qoa	older alluvium, middle to early Pleistocene	5.00		
1127	SJ100	Soil	Qoa?	older alluvium, middle to early Pleistocene	5.00		
1128	SJ100	Soil	Qof	older alluvial fan deposits, middle to early Pleistocene	5.00		
1129	SJ100	Soil	Qof?	older alluvial fan deposits, middle to early Pleistocene	5.00		
1130	SC	Soil	Qcu	coastal terrace deposits, Pleistocene	5.00	Pleistocene	Pleistocene
1131	SC	Soil	Qmt		5.00		
1132	OAK	Soil	Qmt	Marine terrace deposits	5.00		
1133	LOMA	Soil	Qmt		5.00		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1134	LOMA	Soil	Qoa	Older alluvium, undivided	5.00		
1135	MO100	Soil	Qmt	marine terrace deposits, Quaternary	5.00		
1136	MO100	Soil	Qmt?	marine terrace deposits, Quaternary	5.00		
1137	MO100	Soil	Qo		5.00		
1138	MO100	Soil	Qo?		5.00		
1139	MWS	Soil	Qoa	Older alluvial deposits undivided	5.00	Pleistocene	Pleistocene
1140	MWS	Soil	Qoa?	Older alluvial deposits undivided, identification uncertain	5.00	Pleistocene	Pleistocene
1141	TR_GEO4	Soil	Qoa	Early to late Pleistocene alluvial deposits, undivided. Alluvial f	5.00	late Pleistocene	Early Pleistocene
1142	PE_GEO10	Soil	Qoa	Early to late Pleistocene alluvial deposits, undivided. Alluvial f	5.00	late Pleistocene	Early Pleistocene
1143	PE_GEO10	Soil	Qot	Terrace deposit. Moderately indurated, iron-stained, cobble to bou	5.00	Early Pleistocene	Early Pleistocene
1144	NOVA_GEO9	Soil	Qoa	Early to late Pleistocene alluvial deposits, undivided. Alluvial f	5.00	late Pleistocene	Early Pleistocene
1145	FAIR_GEO3	Soil	Qop	Fan or terrace deposits.	5.00	middle Pleistocene	Early Pleistocene
1146	NESF	Soil	Qa	alluvium, Quaternary	5.00		
1147	NESF	Soil	Qf	alluvial fan deposits, Quaternary	5.00		
1148	NESF	Soil	Qpb	basin deposits, late Pleistocene	5.00		
1149	NESF	Soil	Qpf	alluvial fan deposits, late Pleistocene	5.00		
1150	NESF	Soil	Qt	terrace deposits, Quaternary	5.00		
1151	ESWN	Soil	Qa	alluvium, Quaternary	5.00		
1152	ESWN	Soil	Qf		5.00		
1153	ESWN	Soil	Qpa	alluvium, Pleistocene	5.00		
1154	ESWN	Soil	Qpf		5.00		
1155	ESWN	Soil	Qpt	terrace deposits, Pleistocene	5.00		
1156	ESWN	Soil	Qt	terrace deposits, Quaternary	5.00		
1157	WSO	Soil	Qal	alluvial fan and fluvial deposits, Quaternary	5.00		
1158	MA	Soil	Qal	Alluvium	5.00	Quaternary	Quaternary
1159	MA	Soil	Qr	Volcanic gravel	5.00	Quaternary	Quaternary
1160	MA	Soil	Qu	Undifferentiated surficial deposits	5.00		
1161	AL_CC	Soil	Qpaf	alluvial fan and fluvial deposits, Pleistocene	5.00		
1162	AL_CC	Soil	Qpafl	alluvial terrace deposits, first, Pleistocene	5.00		

ID	SRC_MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1163	AL_CC	Soil	Qpaf2	alluvial terrace deposits, second, Pleistocene	5.00		
1164	AL_CC	Soil	Qpf		5.00		
1165	SFS	Soil	Qu	sedimentary deposits, Pleistocene	5.00	Pleistocene	Pleistocene
1166	SM	Soil	Qpaf	alluvial fan and fluvial deposits, Pleistocene	5.00		
1167	PA100	Soil	Qpaf	alluvial fan and fluvial deposits, Pleistocene	5.00		
1168	PA100	Soil	Qpafl	alluvial terrace deposits, Pleistocene	5.00		
1169	SJ100	Soil	Qa	alluvium, Quaternary	5.00		
1170	SJ100	Soil	Qpa	alluvium, late Pleistocene	5.00		
1171	SJ100	Soil	Qpa?	alluvium, late Pleistocene	5.00		
1172	SJ100	Soil	Qpf	alluvial fan deposits, late Pleistocene	5.00		
1173	SJ100	Soil	Qt	stream terrace deposits, Quaternary	5.00		
1174	SJ100	Soil	Qt?	stream terrace deposits, Quaternary	5.00		
1175	SSC	Soil	Qpaf	alluvial fan and fluvial deposits, Pleistocene	5.00		
1176	SSC	Soil	Qpafl	alluvial terrace deposits, Pleistocene	5.00		
1177	SC	Soil	Qaf	Aromas Sand, fluvial	5.00		
1178	SC	Soil	Qal	alluvial deposits, Quaternary	5.00	Quaternary	Quaternary
1179	SC	Soil	Qcl	lowest emergent coastal terrace deposits	5.00		
1180	SC	Soil	Qt	terrace deposits, Pleistocene	5.00	Pleistocene	Pleistocene
1181	SC	Soil	Qwf	terrace deposits of Watsonville, fluvial facies, Pleistocene	5.00	Pleistocene	Pleistocene
1182	OAK	Soil	Qpaf	Alluvial fan and fluvial deposits	5.00	Pleistocene	Pleistocene
1183	OAK	Soil	Qpafl	Alluvial terrace deposits	5.00		
1184	OAK	Soil	Qpoaf	Older alluvial fan deposits	5.00		
1185	LOMA	Soil	Qa		5.00		
1186	LOMA	Soil	Qad		5.00		
1187	LOMA	Soil	Qaf		5.00		
1188	LOMA	Soil	Qal	Alluvium, undivided	5.00		
1189	LOMA	Soil	Qpf	Alluvial fan deposits	5.00		
1190	LOMA	Soil	Qpf?	identification uncertain	5.00		
1191	LOMA	Soil	Qt	Alluvial terrace deposits, undivided	5.00		
1192	LOMA	Soil	Qt?	Alluvial terrace deposits, undivided. identification uncertain	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1193	MO100	Soil	Q	alluvium, Quaternary	5.00		
1194	MO100	Soil	Q?	alluvium, Quaternary	5.00		
1195	MO100	Soil	Qaf	Aromas Sand, fluvial	5.00		
1196	MO100	Soil	Qaf?	Aromas Sand, fluvial	5.00		
1197	MO100	Soil	Qf	alluvial fan deposits, Pleistocene	5.00		
1198	MO100	Soil	Qf?	alluvial fan deposits, Pleistocene	5.00		
1199	MO100	Soil	Qfa	Fan deposits of Antioch	5.00		
1200	MO100	Soil	Qfa?	Fan deposits of Antioch	5.00		
1201	MO100	Soil	Qfc	Fan deposits of Chular	5.00		
1202	MO100	Soil	Qfc?	Fan deposits of Chular	5.00		
1203	MO100	Soil	Qfg		5.00		
1204	MO100	Soil	Qfg?		5.00		
1205	MO100	Soil	Qfp	Fan deposits of Placentia	5.00		
1206	MO100	Soil	Qfp?	Fan deposits of Placentia	5.00		
1207	MO100	Soil	Qms	marine sediments, Quaternary	5.00		
1208	MO100	Soil	Qt	terrace deposits, Pleistocene	5.00		
1209	MO100	Rock	Qt?	terrace deposits+D393, Pleistocene?	5.00		
1210	MO100	Rock	Qtw?	Terrace deposits of Watsonville?	5.00		
1211	MWS	Soil	Qal	Alluvial deposits	5.00	Holocene	Pleistocene
1212	MWS	Soil	Qc	Colluvium	5.00	Holocene	Pleistocene
1213	MWS	Soil	Qt	Alluvial deposits, undivided	5.00	Holocene	Pleistocene
1214	MWS	Soil	Qt?	Alluvial deposits, undivided, identification uncertain	5.00	Holocene	Pleistocene
1215	TR_GEO4	Soil	Qa	alluvium, Quaternary	5.00		
1216	TR_GEO4	Soil	Qf	alluvial fan deposits. Sand, gravel, silt, and clay mapped on gent	5.00	Holocene	Latest Pleistocene
1217	TR_GEO4	Soil	Qpf	fan deposits. Sand, gravel, silt, and clay that is moderately to	5.00	Latest Pleistocene	Latest Pleistocene
1218	PE_GEO10	Soil	Qa	alluvium, Quaternary	5.00		
1219	PE_GEO10	Soil	Qf	alluvial fan deposits. Sand, gravel, silt, and clay mapped on gent	5.00	Holocene	Latest Pleistocene
1220	PE_GEO10	Soil	Qpf	fan deposits. Sand, gravel, silt, and clay that is moderately to	5.00	Latest Pleistocene	Latest Pleistocene
1221	NOVA_GEO9	Soil	Qc	Colluvium. Unconsolidated and unsorted weathered rock fragments ac	5.00		
1222	NOVA_GEO9	Soil	Qpf	fan deposits. Sand, gravel, silt, and clay that is moderately to	5.00	Latest Pleistocene	Latest Pleistocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1223	CORD_GEO8	Soil	Qa	alluvium, Quaternary	5.00		
1224	CORD_GEO8	Soil	Qf	alluvial fan deposits. Sand, gravel, silt, and clay mapped on gent	5.00	Holocene	Latest Pleistocene
1225	CORD_GEO8	Soil	Qpf	fan deposits. Sand, gravel, silt, and clay that is moderately to	5.00	Latest Pleistocene	Latest Pleistocene
1226	FAIR_GEO3	Soil	Qa	alluvium, Quaternary	5.00		
1227	FAIR_GEO3	Soil	Qf	alluvial fan deposits. Sand, gravel, silt, and clay mapped on gent	5.00	Holocene	Latest Pleistocene
1228	FAIR_GEO3	Soil	Qpf	fan deposits. Sand, gravel, silt, and clay that is moderately to	5.00	Latest Pleistocene	Latest Pleistocene
1229		Soil	Qof	terrace deposits of Watsonville, alluvial fan facies, Pleistocene	5.00		
1230	NESF	Soil	Qds	Dune sands, Quaternary	5.00		
1231	WSO	Soil	Qs	beach and dune sand, Quaternary	5.00		
1232	MA	Soil	Qd	Dune sand	5.00	Quaternary	Quaternary
1233	MA	Soil	Qs	Beach sand	5.00	Quaternary	Quaternary
1234	PR	Soil	Qd	dune sands, Holocene	5.00		
1235	PR	Soil	Qod	older dune sands, Pleistocene	5.00		
1236	PR	Soil	Qs	beach sand, Holocene	5.00		
1237	AL_CC	Soil	Qds	dune sand	5.00		
1238	AL_CC	Soil	Qhds	dune sand, Holocene (should be Qds?) MAPPED IN DELTA	5.00		
1239	AL_CC	Soil	Qhms	Merritt Sand (should be Qms?) (Qhms in Oakland quads)	5.00		
1240	SFS	Soil	Qd	dune sands, Holocene	5.00		
1241	PA100	Soil	Qs	sand dune and beach deposits, Holocene	5.00		
1242	SC	Soil	Qae	Aromas Sand, eolian	5.00		
1243	SC	Soil	Qar	Aromas Sand, Pleistocene	5.00	Pleistocene	Pleistocene
1244	SC	Soil	Qbs	beach sand, Holocene	5.00	Holocene	Holocene
1245	SC	Soil	Qce	coastal terrace deposits, eolian facies, Pleistocene	5.00	Pleistocene	Pleistocene
1246	SC	Soil	Qds	dune sands, Holocene	5.00	Holocene	Holocene
1247	SC	Soil	Qem	eolian deposits of Manresa Beach	5.00		
1248	SC	Soil	Qes	eolian deposits of Sunset Beach	5.00		
1249	OAK	Soil	Qds	Dune sand	5.00		
1250	OAK	Soil	Qhbr	Beach ridge deposits	5.00		
1251	OAK	Soil	Qms	Merrit sand	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1252	OAK	Soil	Qms	Merritt Sand	5.00		
1253	MO100	Soil	Qae	Aromas Sand, eolian	5.00		
1254	MO100	Soil	Qar	Aromas Sand	5.00		
1255	MO100	Soil	Qe	eolian sand, Holocene	5.00		
1256	MO100	Soil	Qe?	eolian sand, Holocene	5.00		
1257	MO100	Soil	Qod	dune sand, older Quaternary	5.00		
1258	MO100	Soil	Qod?	dune sand, older Quaternary	5.00		
1259	MO100	Soil	Qs	sand, Quaternary	5.00		
1260	NESF	Soil	Qls	landslide deposits, Quaternary	5.00		
1261	ESWN	Soil	Qls	landslide deposits, Quaternary	5.00		
1262	ESWN	Soil	Qlsa	landslide deposits, andesitic clasts, Quaternary	5.00		
1263	ESWN	Soil	Qlso	landslide deposits, older Quaternary	5.00		
1264	ESWN	Soil	Qlsr	landslide deposits, rhyolite clasts, Quaternary	5.00		
1265	WSO	Soil	Qls	landslide deposits, Quaternary	5.00		
1266	MA	Soil	Qls	Landslide deposits	5.00	Quaternary	Quaternary
1267	MA	Soil	Qsr	Slope debris and ravine fill	5.00	Quaternary	Quaternary
1268	PR	Soil	Qls	landslide deposits, Quaternary	5.00		
1269	AL_CC	Soil	Qls	landslide deposits	5.00		
1270	SFS	Soil	Ql	landslide deposits, Holocene	5.00		
1271	SFS	Soil	Ql(?)	landslide deposits, Holocene	5.00		
1272	SFS	Soil	Qsr	slope debris and ravine fill, Pleistocene	5.00		
1273	SM	Soil	Qcl	colluvium, Quaternary	5.00		
1274	SM	Soil	Qs	sand dune and beach deposits, Holocene	5.00		
1275	PA100	Soil	Qcl	colluvium, Holocene	5.00		
1276	PA100	Soil	Qls	landslide deposits, Quaternary	5.00		
1277	SJ100	Soil	Qc	colluvium, Quaternary	5.00		
1278	SJ100	Soil	Qls	landslide deposits, Quaternary	5.00		
1279	SJ100	Soil	Qls?	landslide deposits, Quaternary	5.00		
1280	SSC	Soil	Qls	landslide deposits, Quaternary	5.00		
1281	SC	Soil	Qtl	colluvium, Holocene	5.00	Holocene	Holocene
1282	OAK	Soil	Qls	Landslide deposits	5.00		
1283	LOMA	Soil	Qls	Landslide deposits, undivided	5.00		
1284	LOMA	Soil	Qls?	Landslide deposits, undivided, identification uncertain	5.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1285	MO100	Soil	Qls	landslide deposits, Quaternary	5.00		
1286	MO100	Soil	Qls?	landslide deposits, Quaternary	5.00		
1287	MWS	Soil	Qls	Landslide deposits	5.00	Holocene	Pleistocene
1288	MWS	Soil	Qls?	Landslide deposits, identification uncertain	5.00	Holocene	Pleistocene
1289	TR_GEO4	Soil	Qls	Landslid deposits	5.00		
1290	PE_GEO10	Soil	Qls	Landslid deposits	5.00		
1291	NOVA_GEO9	Soil	Qls	Landslid deposits	5.00		
1292	CORD_GEO8	Soil	Qls	Landslid deposits	5.00		
1293	FAIR_GEO3	Soil	Qls	Landslid deposits	5.00		
1294	NESF	Soil	Qmz	Montezuma Formation	5.00		
1295	NESF	Rock	QTh	Huichica Formation	4.50		
1296	NESF	Rock	QThg?	Huichica and Glen Ellen Formations, undivided	4.50	early Pleistocene	Pliocene
1297	NESF	Rock	QTu	sandstone, siltstone, gravel, early Pleistocene and(or) Pliocene,	4.50		
1298	ESWN	Rock	QTc	Cache Formation	1.50		
1299	ESWN	Rock	QTc?	Cache Formation	1.50		
1300	ESWN	Rock	QTge	Glen Ellen Formation	4.50		
1301	ESWN	Rock	QThg	Huichica and Glen Ellen Formations	5.00		
1302	WSO	Rock	QTge	Glen Ellen Formation	5.00		
1303	WSO	Rock	QTget	Glen Ellen Formation, tuffaceous member	4.00		
1304	MA	Rock	QTm	Merced Formation	4.50		
1305	AL_CC	Rock	QTgt		5.00		
1306	AL_CC	Rock	QTi	Irvington gravels	4.50		
1307	AL_CC	Rock	QTl	Livermore gravels	4.50		
1308	AL_CC	Rock	QTl?	Livermore gravels	4.50		
1309	AL_CC	Rock	QTu	gravels, Pleistocene and(or) Pliocene	4.50		
1310	SFS	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		
1310	SFS	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		
1310	SFS	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		
1311	SM	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1311	SM	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		
1311	SM	Rock	QTm	Merced Formation (upper Pliocene to Pleistocene)	4.50		
1312	SM	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1312	SM	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1312	SM	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1313	PA100	Rock	QTm	Merced Formation	4.50		
1313	PA100	Rock	QTm	Merced Formation	4.50		
1313	PA100	Rock	QTm	Merced Formation	4.50		
1314	PA100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1314	PA100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1314	PA100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1315	PA100	Rock	QTsl	Santa Clara Formation, lake beds, Stevens Creek	4.50	Early Pleistocene	Late Pliocene
1315	PA100	Rock	QTsl	Santa Clara Formation, lake beds, Stevens Creek	4.50	Early Pleistocene	Late Pliocene
1315	PA100	Rock	QTsl	Santa Clara Formation, lake beds, Stevens Creek	4.50	Early Pleistocene	Late Pliocene
1316	SJ100	Rock	QTi	Irvington gravels	4.50		
1316	SJ100	Rock	QTi	Irvington gravels	4.50		
1316	SJ100	Rock	QTi	Irvington gravels	4.50		
1317	SJ100	Rock	QTp	Packwood gravels	4.50		
1317	SJ100	Rock	QTp	Packwood gravels	4.50		
1317	SJ100	Rock	QTp	Packwood gravels	4.50		
1318	SJ100	Rock	QTp?	Packwood gravels?	4.50		
1318	SJ100	Rock	QTp?	Packwood gravels?	4.50		
1318	SJ100	Rock	QTp?	Packwood gravels?	4.50		
1319	SJ100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1319	SJ100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1319	SJ100	Rock	QTsc	Santa Clara Formation	4.50	Early Pleistocene	Late Pliocene
1320	SSC	Rock	QTp	Packwood gravels	4.50		
1320	SSC	Rock	QTp	Packwood gravels	4.50		
1320	SSC	Rock	QTp	Packwood gravels	4.50		
1321	SC	Rock	Qtc	continental deposits, Pleistocene and(or) Pliocene	2.50	Pleistocene	Pliocene

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1321	SC	Rock	Qtc	continental deposits, Pleistocene and(or) Pliocene	2.50	Pleistocene	Pliocene
1321	SC	Rock	Qtc	continental deposits, Pleistocene and(or) Pliocene	2.50	Pleistocene	Pliocene
1322	OAK	Rock	QTi?	Irvington gravels, identification uncertain	5.00		
1323	OAK	Rock	QTu	Undifferentiated continental gravels	5.00	Pleistocene	Pliocene
1324	LOMA	Rock	QTf	Fluvial deposits, undivided (Pleistocene and Pliocene?)	4.00	Pleistocene	Pliocene?
1325	LOMA	Rock	QTsc	Santa Clara Formation (Pleistocene and Pliocene)	4.50	Early Pleistocene	Late Pliocene
1326	LOMA	Rock	QTsc?	Santa Clara Formation (Pleistocene and Pliocene)	4.50	Early Pleistocene	Late Pliocene
1327	MO100	Rock	QT	continental deposits,	4.50	Pleistocene	Pliocene
1328	MO100	Rock	QT?	continental deposits, Pleistocene and(or) Pliocene?	4.50	Pleistocene	Pliocene
1329	MO100	Rock	QTf	fluvial deposits, Pleistocene and(or) Pliocene	4.50	Pleistocene	Pliocene
1330	MWS	Rock	QTg	Fluvial and lacustrine deposits	4.50	early Pleistocene	Pliocene
1331	MWS	Rock	QTg?	Fluvial and lacustrine deposits, identification uncertain	4.50	early Pleistocene	Pliocene
1332	MWS	Rock	QTgd	Marine diatomite	1.50	early Pleistocene	Pliocene
1333	MWS	Rock	QTgs	Siltstone marker beds	2.75	early Pleistocene	Pliocene
1334	MWS	Rock	QTgt	Siliceous tuff marker beds	1.50	early Pleistocene	Pliocene
1335	ESWN	Soil	Qr	Clear Lake volcanics, rhyolite	1.50		
1336	ESWN	Rock	QTob	Clear Lake volcanics, olivine basalt	1.50		
1337	ESWN	Rock	QTt	Clear Lake Volcanics, tuff	1.50		
1338	ESWN	Rock	Tr	Clear Lake volcanics, rhyolite	1.50		
1339	WSO	Soil	Qob	Clear Lake volcanics, olivine basalt	1.50		
1340	WSO	Soil	Qr	Clear Lake volcanics, rhyolite and rhyodacite	1.50		
1341	SSC	Rock	QTv	volcanic rocks, Calveras Fault Zone	2.00	Pleistocene	Pliocene
1341	SSC	Rock	QTv	volcanic rocks, Calveras Fault Zone	2.00	Pleistocene	Pliocene
1341	SSC	Rock	QTv	volcanic rocks, Calveras Fault Zone	2.00	Pleistocene	Pliocene
1342	WSO	Rock	TKfs	Franciscan Complex, Coastal or Central Belt, graywacke	1.50	Late Eocene	Late Createcous
1343	WSO	Rock	TKfss	Franciscan Complex, Coastal Belt, graywacke	1.50	Late Eocene	Late Createcous

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1344	WSO	Rock	TKfgs	Franciscan Complex, Coastal Belt, greenstone	1.50	Late Eocene	Late Createcous
1345	WSO	Rock	TKu	undifferentiated German Rancho and Gualala Formations	2.50	Late Eocene	Late Createcous
1346	MO100	Rock	TKu	sedimentary rock, Paleocene and(or) Cretaceous, Vallecitos Synclin	2.50	Paleocene	Creatceous
1347	SF_UNION	Rock	water	water	1.00		
1347	SF_UNION	Rock	water	water	1.00		
1347	SF_UNION	Rock	water		1.00		
1348	NESF	Rock	water	water	1.00		
1349	ESWN	Rock	water	water	1.00		
1350	WSO	Rock	water	water	1.00		
1351	MA	Rock	water	water	1.00		
1352	PR	Rock	water	water	1.00		
1352	PR	Rock	water	water	1.00		
1352	PR	Rock	water		1.00		
1353	AL_CC	Rock	water	water	1.00		
1354	SFS	Rock	water	water	1.00		
1354	SFS	Rock	water	water	1.00		
1354	SFS	Rock	water	water	1.00		
1355	SM	Rock	water	water	1.00		
1355	SM	Rock	water	water	1.00		
1355	SM	Rock	water	water	1.00		
1356	PA100	Rock	water	water	1.00		
1356	PA100	Rock	water	water	1.00		
1356	PA100	Rock	water	water	1.00		
1357	SJ100	Rock	water	water	1.00		
1357	SJ100	Rock	water	water	1.00		
1357	SJ100	Rock	water	water	1.00		
1358	SSC	Rock	water	water	1.00		
1358	SSC	Rock	water	water	1.00		
1358	SSC	Rock	water	water	1.00		
1359	SC	Rock	water	water	1.00		
1359	SC	Rock	water	water	1.00		
1359	SC	Rock	water	water	1.00		
1360	OAK	Rock	water	water	1.00		
1361	LOMA	Rock	water	water	1.00		

ID	SRC__MAP	MATERIAL	ORIG_PTYPE	DESCRIPT	MCLASS	MIN_AGE	MAX_AGE
1362	MO100	Rock	water	water	1.00		
1363	MWS	Rock	water	water	1.00		
1364	TR_GEO4	Rock	water	water	1.00		
1365	PE_GEO10	Rock	water	water	1.00		
1365	PE_GEO10	Rock	water	water	1.00		
1365	PE_GEO10	Rock	water	water	1.00		
1366	NOVA_GEO9	Rock	water	water	1.00		
1367	CORD_GEO8	Rock	water	water	1.00		
1368	FAIR_GEO3	Rock	water	water	1.00		
1369	ESWN	Rock	Jko		2.50		
1370	MA	Rock	stack	Sea stack (unlabel polygon)	2.50		
1371	SFS	Rock	fr	fault rocks	3.00		
1371	SFS	Rock	fr	fault rocks	3.00		
1371	SFS	Rock	fr	fault rocks	3.00		
1372	SFS	Rock	stack	Sea stack (unlabel polygon)	2.50		
1372	SFS	Rock	stack	Sea stack (unlabel polygon)	2.50		
1372	SFS	Rock	stack	Sea stack (unlabel polygon)	2.50		
1373	SJ100	Rock	gi		1.50		
1373	SJ100	Rock	gi		1.50		
1373	SJ100	Rock	gi		1.50		
1374	SJ100	Rock	sill		2.50		
1374	SJ100	Rock	sill		2.50		
1374	SJ100	Rock	sill		2.50		
1375	SSC	Rock	tar	not in explanation, tar seeps at Sargent oil field	1.00		
1375	SSC	Rock	tar	not in explanation, tar seeps at Sargent oil field	1.00		
1375	SSC	Rock	tar	not in explanation, tar seeps at Sargent oil field	1.00		
1376	MWS	Rock	QThg		2.50		
1377		Soil	Qls	Landslides	5.00		
1378		Rock			2.50		
1379		Rock			2.50		
1380		Rock			2.50		
1381		Rock			2.50		

APPENDIX C: SUMMARY OF LANDSLIDES FROM LAWSON IN YOUD AND HOOSE 1978

Location Number on Map	Quantity of Landslides	Size	Location	Type of Landslide	Evidence
Monterey					
39	several		hillside	unknown	
41			hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
Santa Cruz Mountains					
45	several		hillside	unknown	small and unimportant
46	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	
48	several			rock falls/disrupted rock slides	solid and massive rock outcrop
50	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
	1		hillside	soil falls/disrupted soil slides; soil slumps/soil block slides	earth avalanches
51	several		hillside	unknown	
54	several		hillside	unknown	
55	1		hillside	rock falls/disrupted rock slides	photo
	1		hillside	unknown	
	1		hillside	unknown	
56	1		hillside	unknown	
	1		hillside	unknown	
	several		hillside	unknown	
58	1		hillside	rock slumps/rock block slides	
61	several		hillside	soil falls/disrupted soil slides	
	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
62	several		hillside	rock slumps/rock block slides	coincident with bedding
63	several		hillside	unknown	
66	1		hillside	rapid soil flow	spring related
67			hillside	rock falls/disrupted rock slides	ledge of shale fell
68			hillside	soil falls/disrupted soil slides	carried and overturned trees
			hillside	soil falls/disrupted soil slides	carried and overturned trees
70	1		hillside	soil falls/disrupted soil slides	earthslide
71	1		hillside	unknown	
72			hillside	soil falls/disrupted soil slides	soil shaken loose from an abrupt hill
			hillside	soil falls/disrupted soil slides	hill and soil shaken loose
74	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
	1	large	hillside	rock falls/disrupted rock slides	rock falls joined earth avalanche
			hillside	soil falls/disrupted soil slides	
75	1	small	hillside	unknown	

Location Number on Map	Quantity of Landslides	Size	Location	Type of Landslide	Evidence
76	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
77			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
78	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
79	1		hillside	soil slumps/soil block slides	solid pieces
			hillside	unknown	
80	1		hillside	unknown	
	1		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	steep face of an bluff
81	1	large	hillside	soil slumps/soil block slides	terraced from the top
82	1		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
	several	large	hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	fell rock and trees
83	few		hillside	rock falls/disrupted rock slides	sandstone blocks rolled
	some		hillside	rock falls/disrupted rock slides	sandstone blocks rolled
84		large	hillside	soil slumps/soil block slides	no deformation, intact
85		large	hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
86		large	hillside	soil falls/disrupted soil slides	
			hillside	soil slumps/soil block slides	
87		small	hillside	rapid soil flow	landslip
89	several		streambank	soil falls/disrupted soil slides	caving of streambank
91			hillside	rock falls/disrupted rock slides	rock rolled down the hill
92	several		streambank	soil slumps/soil block slides	half-moon shaped scarp
94	1		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
95	1	large	hillside	unknown	
96	1	large	hillside	unknown	
97			hillside	unknown	
98	few		hillside	soil slumps/soil block slides	big, dropped down
99	several		hillside	rock falls/disrupted rock slides	rock from the top
	several	large	hillside	rock falls/disrupted rock slides	rocks rolled onto road
100	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
101	several		hillside	rapid soil flow	
102	2		hillside	unknown	
104	several		hillside	rapid soil flow	landslip
105	some	small	hillside	soil slumps/soil block slides	small cracks
106	1		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	landslip
	1		hillside	soil falls/disrupted soil slides	earthslide
107	1	large	hillside	unknown	
108	1	large	hillside	unknown	
110	several		hillside	rapid soil flow	flow
	several		hillside	soil slumps/soil block slides	
111			hillside	rapid soil flow	scarp flow
112	1	large	hillside	soil falls/disrupted soil slides	earthslide
113		large	hillside	rapid soil flow	earth flow
114	2	small	hillside	rapid soil flow	
115	several	large	hillside	rock falls/disrupted rock slides	slipping of large block of rocks
			hillside	rock falls/disrupted rock slides	blocks of sandstone fell on the road
119	several		hillside	soil slumps/soil block slides	slipping of the earth
121	several		hillside	soil slumps/soil block slides	
122	several	large	hillside	unknown	
		small	hillside	unknown	
123	2	large	hillside	rapid soil flow	flows
		small	hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
127	several		hillside	soil falls/disrupted soil slides	decomposed granite; coastal bluff

Location Number on Map	Quantity of Landslides	Size	Location	Type of Landslide	Evidence
128	several		hillside	soil falls/disrupted soil slides	weathered granite and sandstone
	several		hillside	soil falls/disrupted soil slides	
130	several	small	hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
131	several		hillside	soil falls/disrupted soil slides	cliffs involving soil
			hillside	soil falls/disrupted soil slides	
			hillside	soil falls/disrupted soil slides	
			hillside	rock falls/disrupted rock slides	
			hillside	soil falls/disrupted soil slides	
133	several	large	hillside	soil falls/disrupted soil slides	dirt that had fallen
	several	large	hillside	soil falls/disrupted soil slides	earth fall
			hillside	unknown	
134			hillside	unknown	
135	1	large	hillside	rapid soil flow	flow
			hillside	rapid soil flow	earth flow
San Francisco Bay, Santa Clara Valley, and East Bay Hills					
136	few		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
149	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
154	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
160	1	large	hillside	soil falls/disrupted soil slides	no cracks
167			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
170			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
172			hillside	unknown	
175			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
178			hillside	unknown	
179	several		hillside	soil slumps/soil block slides	relatively intact, hummocky surface
180	few	small	hillside	rock falls/disrupted rock slides	rock slide
184	1		hillside	soil falls/disrupted soil slides	uneven scarps
185	few		hillside	soil slumps/soil block slides	large blocks
186			hillside	unknown	
187			hillside	soil slumps/soil block slides	fissures bulged upward
			hillside	soil falls/disrupted soil slides	bluff 40 - 60 ft. fall
188	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	coastal bluffs
			hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	coastal bluffs
			hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	coastal bluffs
189			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
190			hillside	rock falls/disrupted rock slides	rocks rolled
San Francisco City and County					
218	1		hillside	rapid soil flow	sand layer shaking downhill
222	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
226	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
227	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
228			hillside	soil slumps/soil block slides; rock slumps/rock block slides	concentric steps
			hillside	unknown	

Location Number on Map	Quantity of Landslides	Size	Location	Type of Landslide	Evidence
229			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
			streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
231	several		hillside	rapid soil flow	dune sand
245	1	large	hillside	soil falls/disrupted soil slides	covered over road
North Bay Counties					
249		large	streambank	soil slumps/soil block slides	large slump
261		large	hillside	soil slumps/soil block slides; rock slumps/rock block slides	several buildings slide downhill together
274	2		hillside	rapid soil flow	wet slides
276			hillside	soil falls/disrupted soil slides	falls of earth
			hillside	soil falls/disrupted soil slides	falls of earth
279			hillside	unknown	
285			hillside	unknown	
291			hillside	unknown	
294			hillside	unknown	
296	several		streambank	rapid soil flows; soil falls/disrupted soil slides; soil slumps/soil block slides	streambank types
297	few		hillside	rapid soil flow	alluvium
298	1	large	hillside	rock slumps/rock block slides	dip of bedding; stratified volcanics
300	several		hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	earth avalanches
301	several	large	hillside	soil falls/disrupted soil slides; rock falls/disrupted rock slides	fallen timbers
302	several	large	hillside	unknown	
303	several		streambank	soil falls/disrupted soil slides; soil slumps/soil block slides	
	several		hillside	soil falls/disrupted soil slides	

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

June 27, 2007

Mr. Gary Taylor
Geological Survey Publications
801 K Street, MS 14-33
Sacramento, CA 95814.

Dear Mr. Taylor:

I am completing a master's thesis at San Jose State University entitled "Computer Modeling of Landslides Generated by the 1906 San Francisco Earthquake." I would like your permission to reprint in my thesis excerpts from the following:

Jennings, C.W., 1994, Fault activity map of California and adjacent areas: California Division of Mines and Geology, Geologic Data Map GDM No. 6, scale 1:750 000.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my thesis by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company owns] the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me. Thank you very much.

Sincerely,

Mr. Gary Taylor

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE

Date: 6/28/07

Mail Message

Reply Read Later

Mail Properties

From: Graham Hancox <gthancox@paradise.net.nz> Wednesday - June 27, 2007 8:12 PM
To: Mark Swank <MSwank@kleinfelder.com>
CC: <dkeefer@usgs.gov>, <g.dellow@gns.cri.nz>, <n.perrin@gns.cri.nz>
Subject: Re: Thesis Permission Form
Attachments: Hancox Permission (signed by GTH).pdf (16748 bytes) [View] [Open] [Save As]
Mime.822 (33713 bytes) [View] [Save As]

Hello Mark (my apologies...pdf attached this time),

Your are certainly most welcome to use the Table from our 2002, paper, or anything else in it that you find to be relevant and of use in your work. I have signed the pdf form that you sent me and attached it as a pdf file.

Good luck with your thesis. Please give my warmest regards to Dave Keefer, and tell him I plan to visit the US in early December, and hope to be able to catch up with him then.

Hi Dave:
Can you please send me your physical address so I can make my travel arrangements.
(and...will you be about between 15-21 December).

Regards and best wishes

Graham Hancox

[]

Graham T Hancox
Senior Engineering Geologist
GNS Science
Phone: (04) 570 4742 (GNS)
Home: (04) 904 9678; Mobile: (029) 904 9678
email: g.hancox@gns.cri.nz (GNS)
gthancox@paradise.net.nz (home)

At 11:30 a.m. 28/06/2007, you wrote:
>Hello Mr. Graham-
>
>My name is Mark Swank and I am a graduate student at San Jose State

>University in California. I am completing my thesis entitled
>"Computer Modeling of Landslides Generated by the 1906 San
>Franscisco Earthquake" under the guidance of Dr. Dave Keefer at the
>USGS. He has provided me with your contact information. I have
>been requested by my University to attain permission to use any
>figures not created by myself from the original authors. I have
>utilized the attached figure in my thesis and, hence, would like
>your permission. I have also attached a permission form that, if
>you agree with my use of your figure, may be faxed to me at (503)
>643-1905, scanned and emailed to this address, or mailed to:
>
>Mark Swank
>16634 NW Arizona Dr.
>Beaverton, OR 97006
>
>If you would like, I could mail you an envelope with pre-paid
>postage to the above address. In addition, if you would not like me
>to use the figure for any reason, please state this so I may remove
>it from the thesis. If you have any questions I can reached at this
>email address or (503) 703-6008.
>
>Regards,
>
>Mark
>
>Mark Swank
>Kleinfelder, Inc. Portland
>Phone: (503) 644-9447
>Cell: (503) 703-6008
>Fax: (503) 643-1905
>
>

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

June 27, 2007

Dear Mr. Hancox:

I am completing a master's thesis at San Jose State University entitled "Computer Modeling of Landslides Generated by the 1906 San Francisco Earthquake." I would like your permission to reprint in my thesis excerpts from the following:

Hancox, G.T., Perrin, N.D., and Dellow, G.D., 2002, Recent Studies of Historical Earthquake-Induced Landsliding, Ground Damage, and MM Intensity in New Zealand: Bulletin of the New Zealand Society for Earthquake Engineering, vol. 35, No. 2, p. 59–94.

The excerpts to be reproduced are a table from the above report produced by you either used in its entirety or modified.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my thesis by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company owns] the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Mr. Graham Hancox

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE:

Signed by Graham Hancox
GNS Science, Lower Hutt
New Zealand
Date: 29/6/2007

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

June 27, 2007

Dr. Scott B. Miles
Department of Environmental Studies
Western Washington University
516 High St., MS 9079
Bellingham, WA 98225-9079

Dear Dr. Miles:

I am completing a master's thesis at San Jose State University entitled "Computer Modeling of Landslides Generated by the 1906 San Francisco Earthquake." I would like your permission to reprint in my thesis excerpts from the following:

Miles, S.B., 2004, Participatory Assessment of a Comprehensive Areal Model of Earthquake-Induced Landslides, PhD dissertation: University of Washington.

The excerpts to be reproduced are figures from your doctoral dissertation either used in entirety or modified.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my thesis by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company owns] the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Dr. Scott B. Miles

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE:

____

Date: July 2, 2007

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

07/31/07

Dr. Russell Graymer
345 Middlefield Rd- MS 975
Menlo Park, CA 94025

Dear Dr. Graymer:

I am completing a master's thesis at San Jose State University entitled "COMPUTER MODELING OF LANDSLIDES GENERATED BY THE 1906 SAN FRANCISCO EARTHQUAKE." I would like your permission to reprint in my thesis the following map:

Graymer, R.W., Moring, B.C., Saucedo, G.J., Wentworth, C.M., Brabb, E.E., and Knudsen, K.L., 2006, Geologic map of the San Francisco Bay region: U.S. Geological Survey, Scientific Investigations Map SIM-2918, scale 1:275 000.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my dissertation by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that ~~you own [or your company owns] the copyright to~~ the above-described material is in the public domain and can be freely reproduced with proper citation.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Mark Swank

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Dr. Russell Graymer

Date: 8/2/07

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

June 27, 2007

Dr. David K. Keefer
US Geological Survey MS 977
Earthquake Hazards Team
345 Middlefield Rd.
Menlo Park, California 94025.

Dear Dr. Keefer:

I am completing a master's thesis at San Jose State University entitled "Computer Modeling of Landslides Generated by the 1906 San Francisco Earthquake." I would like your permission to reprint in my thesis excerpts from the following:

Keefer, David K., 2000, Statistical Analysis of an Earthquake-Induced Landslide Distribution – the 1989 Loma Prieta, California Event: Engineering Geology. Vol. 58, p. 231–249.

Keefer, D.K., Miles, S., Swank, M., and Blair, J.L., 2006, A CAMEL-based assessment of earthquake-induced landslide hazards in the San Francisco Bay region, California (Abstract): Seismological Society of America Centennial Meeting, San Francisco, April 18-22, 2006, SSA-0125.

Keefer, David K., 1984, Landslides Caused by Earthquakes: Geological Society of America Bulletin. Vol. 95, p. 406–421.

The excerpts to be reproduced are figures from the above listed journal articles and presentation either used in entirety or modified.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my thesis by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company owns] the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Dr. David K. Keefer

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:
David K. Keefer

Date: 27 June 2007

Mark Swank
16634 NW Arizona Dr.
Beaverton, OR 97006

June 27, 2007

Dr. Randall W. Jibson
US Geological Survey MS 966
Earthquake Hazards Team
345 Middlefield Rd.
Menlo Park, California 94025.

Dear Dr. Jibson:

I am completing a master's thesis at San Jose State University entitled "Computer Modeling of Landslides Generated by the 1906 San Francisco Earthquake." I would like your permission to reprint in my thesis excerpts from the following:

Parise, M. and Jibson, R., 2000, A seismic landslide susceptibility rating of geologic units based on analysis of characteristics of landslides triggered by the 17 January, 1994 Northridge, California earthquake: Engineering Geology, vol. 58, p. 251–270.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my thesis by UMI. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company owns] the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me. Thank you very much.

Sincerely,

Dr. Randall W. Jibson

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE:

____

Date: 6/28/07